MAY 2 8 1944

Instruments

THE MAGAZINE OF Measurement and Control

Vol. 17
MAY
1944
No. 5

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pH
Liquid Level
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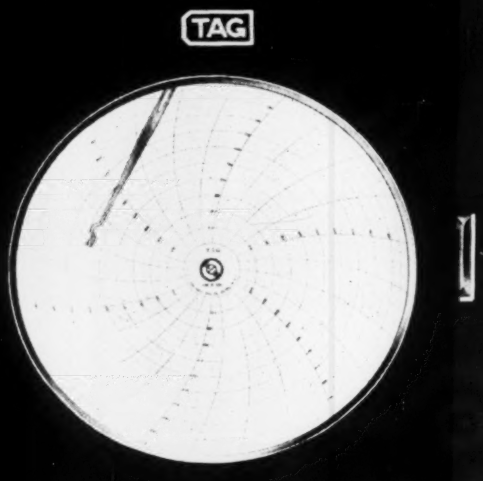

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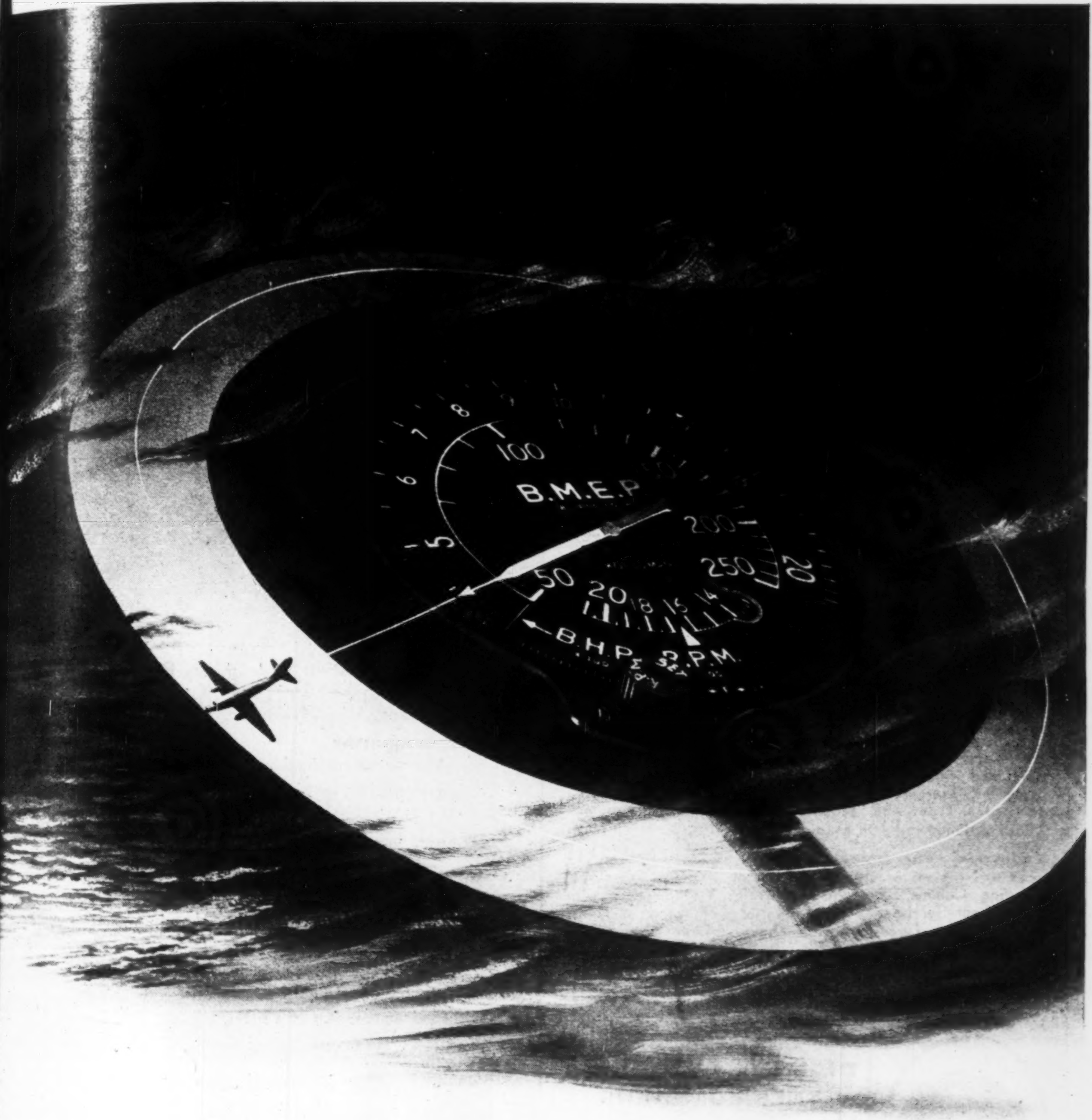

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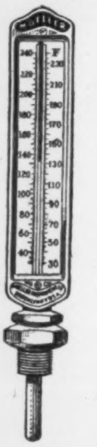

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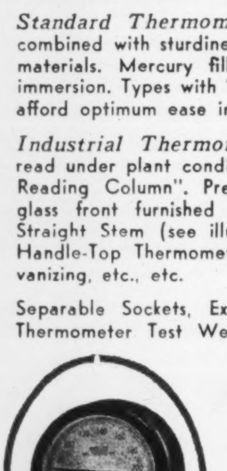

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Vol. 17 MAY 1944 No.

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MANUFACTURERS' NEW LITERATURE

ADVERTISERS' INDEX

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Major M. F. BEHA
Editor

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Instruments THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

Terminology Again

> Men suppose that their reason has command over their words; still it happens that words in return exercise authority on reason.
> —FRANCIS BACON

> TEACHER: "What is a lobster?"
> BOY: "A lobster is a red fish that swims backward."
> TEACHER: "A live lobster is not red; it is not a fish; it does not swim backward; but evidently you know what a lobster is."

IN last month's Aviation Instruments Department there was an article headed "Synchronous Tac Tester." Now, from the greatest authority on electrical instruments comes a long letter mildly chiding me for this heading: Dr. George Keinath implies that I must have known that "synchronous" was incorrect and that "tac" was a vulgarism. He shows a keen understanding of the delicate problems which an editor serving a diversified audience meets in almost every line of every manuscript; but he misses the point that *Aviation Instruments* is "a magazine within a magazine," serving a distinct audience of young aviation enthusiasts who are a distinct LANGUAGE GROUP.*

Stretching points to please these fine young men is in my nature, but catering to various instrument-minded audiences is the policy of The Instruments Publishing Company: our Company is not an endowed institution or bureau but a private enterprise, staying alive if it does a good job of serving its readers, doomed to extinction if it doesn't. Part of our service is to make sure that the varied bill of fare we serve each month will benefit all those who eat the various dishes. When an aviation man, or a member of *any* language-group, submits an article for the "main part" of *Instruments*—a long article or a brief new-instrument description which will be read by members of *all* language groups, it is gone over line by line and word by word, to make sure that it is not printed in his group's language but in the common language of all groups—the Language of Instrumentation. This is not an artificial language which *Instruments* wants to impose on various language groups, but a natural language, a composite language which began to evolve twenty years ago when the American Instrument Society† was created to formulate the Science of Instrumentation.

Instruments' policy is founded on respect for the established usages of all fields. In a manuscript on a mechanical-engineering subject we would not dream of changing the author's term "turbine governor" (which is ASME terminology) to "automatic speed controller" which is the *generic* term in the AIS terminology. Likewise we have always edited manuscripts on purely electrical-engineering subjects to conform to the AIEE's terminology even when certain terms differed from the AIS terminology.

This policy is carried out by our entire organization. For example, while I was "pasting up the dummy" *(printer's terminology!)* I noticed on page 322 a manufacturer's literature item entitled "R.P.M. Controls for A-c. Lines." The devices are speed regulators but the editorial assistant who writes up our new-literature items respected the usages of the electronics field. Complications arise when fields overlap. For example some radio terms differ from those of the AIEE. In such cases, as a rule, we respect seniority or parentage. Thus radio is a branch of electricity; so our obvious duty with articles on electronics (of interest to readers outside the communications field) is to translate them into AIEE language. But when an article on electronic devices deals with topics of interest to *all* our readers in *all* industries, then such an article must obviously be re-worded into the Language of Instrumentation.

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*For a detailed discussion, read "On The Language of Instrumentation." **Instruments**, Aug. 1942, pages 298-305, 320-323.

†I have always given ample space in **Instruments** to the instrumentation activities of the dozen scientific and engineering societies to which I belong, but this is the first mention of the AIS. Some of my old friends have wondered why I suppressed all mentions of it. Perhaps it's false modesty: I founded it. Perhaps it should not die out; perhaps it should be re-activated, because there is need for a national organization like it. In fifteen years I shall reach the three-score-and-ten mark.

Watthour Meter Cups Not Under "Jewel Bearings"

On this page last month appeared a letter from Charles D. Burgess, Jewel Bearings Section, WPB, explaining the removal of several restrictions in the newly-amended Conservation Order M-50. The following letter just received from Mr. Burgess announces a further amendment of M-50:

We are enclosing a copy of Conservation Order M-50 as amended April 14, 1944. Please note that paragraph (a) (2) has been changed to read as follows:

"'Jewel bearing' means any jewel bearing material which has been processed in any manner for use where friction occurs, including vees, rings, cups, endstones, pallet stones, and roller pins. *Watthour meter cups are not included.*"

By inserting the sentence "Watthour meter cups are not included" in the definition of jewel bearings under Conservation Order M-50 as amended December 24, 1943, it now becomes unnecessary for producers, suppliers, or consumers to further report their production or consumption of watthour meter cups.

This means that suppliers, producers, and consumers will have free use of this product, and that there will be no further control of watthour meter cups by War Production Board.

We would appreciate it very much if you would publish the above information in your magazine *Instruments* so that the Public Utility Companies will have information that the restrictions on the use of watthour meter cups have been removed from Conservation Order M-50 and are, therefore, not subject to the control of War Production Board.

PROPOSED THERMIONIC CONTROL INSTRUMENTATION COURSE TO BEGIN JUNE 5, 1944 (Tentatively)

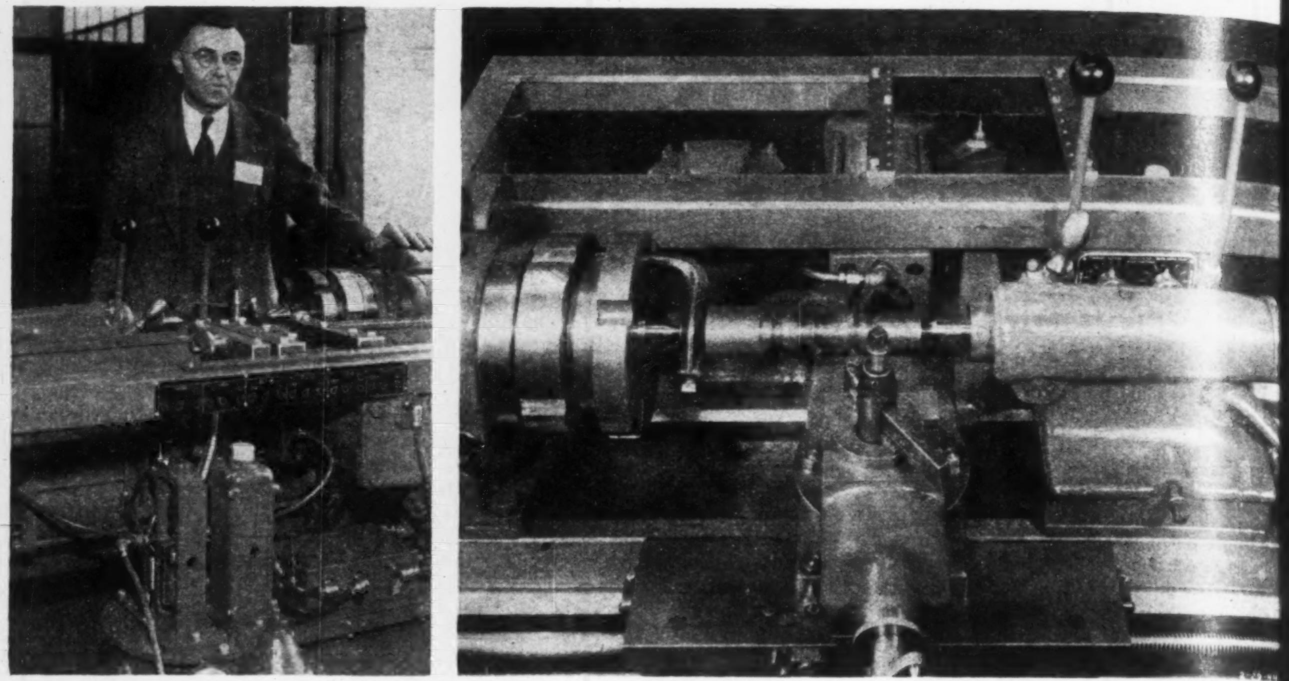
Offered under ESMWT Program. Sponsored by University of Pittsburgh Chemical Engineering Department

Description. To provide a complete understanding of present-day high-speed instruments in which the galvanometer has been replaced by the "radio tube." College physics, two years of actual practice with such equipment, or a ground course in instruments will be required.

The course includes basic training in the theory of the vacuum tube and a-c. and d-c. electricity. Coverage is sufficient for understanding of application of photocells and chopped d-c. input circuits. Basic coverage is also included for resistance-coupled and direct-coupled low-frequency amplifiers, as well as simple oscillator circuits, *complete analysis of four commercial instruments* which operate without use of galvanometer to drive a reversible motor to operate recording pen directly.

Class will meet two evenings a week (6:30-10:30). Each meeting will consist of two hours of lecture and two hours of laboratory work.

In order to start this course it will be necessary that we get at least 25 pledged members. Please communicate with J. A. Pellettere, 458 Gulf Building, P.O. Box 1166, Pittsburgh 30, Pa.



Installation on a 12" Hendey lathe: (Left) Inventor Johnson demonstrates to visiting engineers; (right) operator's-eye view.

A New "Instrumentation-type" Air Gaging Method fo Automatic Control of Machine Tools

By **CLARENCE JOHNSON**, Development Engineer, Bailey Meter Co., Cleveland, Ohio

INSTRUMENTATION principles are utilized in the new method herein disclosed, the purpose of which is to make possible extreme accuracy of repetition (within 0.0002") in the automatic operation of certain types of metal-cutting machine tools.

At the outset, it is necessary to point out that such a degree of precision is not commonplace in the majority of machining operations. Recent accomplishments by the machine-tool industry, by instrument-makers, by aircraft engineers and by tool engineers have been publicized (and rightly!) until a large segment of the technical public believes that dimensional control to a ten-thousandth of an inch or better has become commonplace in modern American industries. The fact is that this degree of precision applies only to gages and to a small percentage of machined products such as gyroscope parts, aircraft engine parts, ball-bearings, etc.—the great majority of interchangeable components being held to a few thousandths of an inch; so that there is ample room for improvement in interchangeability. Moreover—and this is important—the great majority of *types* of high-speed machine tools for quantity production of metal components, even now in 1944, are not designed for such high-precision work *when they operate automatically* instead of being operated by skilled machinists who "mike" each step before going on to the next.

THE WAR IS NOT YET WON
Production MUST be speeded.
Machine-tool *electrification* is advocated
by some; *hydraulics* by others
pneumatic devices; and *electronics*;
a purely *mechanical* solution
or some *composite* systems.
We favor AUTOMATIZATION through
instrumentation whatever its type
to save our boys' lives
and lick the Huns and Japs.
MFB

These things having been pointed out, it will become apparent that there are many fields of application, even today, for a method of automatic control which obviates the need of stopping such machine tools after each cut—a method which can convert many such machine tools into automatic machines, or which can step up the precision of already-automatized machines from a few thousandths of an inch to half a thousandth or better.

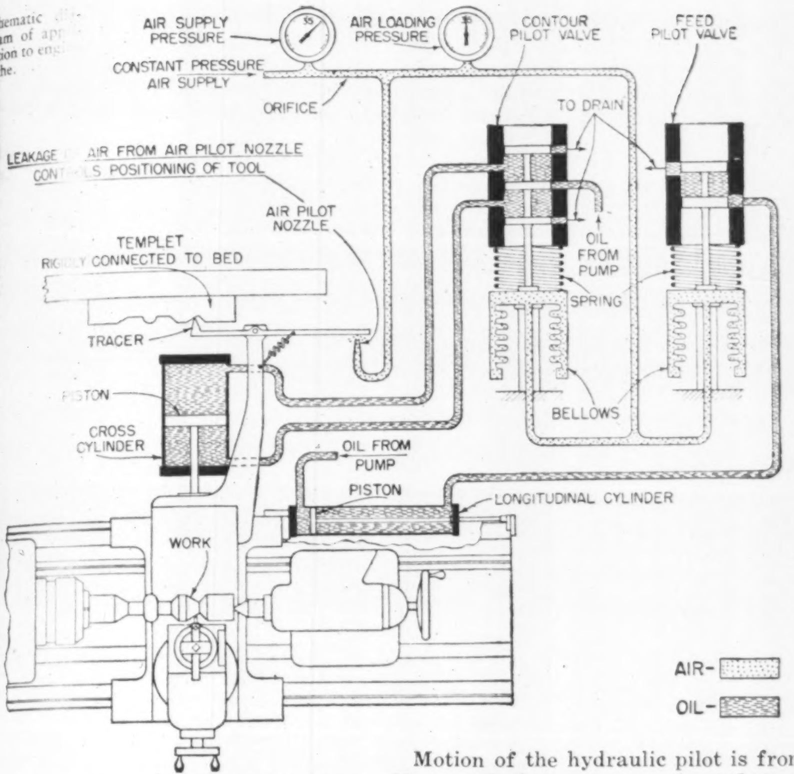
An outstanding field of application of the new method is in turning, boring and facing automatically to the exact contours of templets—the contours including slow and fast tapers, round corners, square shoulders, etc. All diameters and shoulders of a step shaft may be turned with one setting of the tool. Difficult contours which formerly required the use of special forming tools may be turned with one setting of a simple tool.

Contour cutting is one of the oldest problems in shop work and its first solutions appeared more than a century ago, most of them involving the use of a heavy weight acting on the cross-feed through a pulley and limited by a roller on the templet. The results were extremely coarse.

The most modern methods are the ones whereby a standard machine tool such as an engine lathe already at hand or easily available, is operated by powerful means, such as reversing-type electric motors, hydraulic cylinders, etc., under the command of a "brain" which in turn is governed by a simple templet accurately shaped from a thin plate. These methods (including the one under discussion) may be called templet-scanning methods.

Those employing a light-source and a photoelectric tube (or photovoltaic cell) as the scanning device are no doubt familiar to many readers of *Instruments* who keep up with recent electronic developments.

The new method belongs to the other class of templet-scanning methods, which may be called the mechanical class or the physical-contact class by reason of the utilization of a tracer stylus as a scanning device. To many *Instruments* readers who keep up with announcements and discussions of new automatic-control instruments in which there is no mechanical contact between



hematic di- am of app tion to eng the.

he primary element and the prime re-ay, a stylus scanner might seem in-erior to a beam of light. In practice, owever, a stylus scanner is still found he best means of determining surface ontours; and is used for that purpose n both the Abbott Profilometer and he Brush Surface Analyzer, which are xtreme-precision recorders with charts raduated in hundred-thousandths of n inch—even in microinches whenever equired. The new method is capable of *tecting* microinch irregularities in ny individual templet.

With this new method, therefore, the ccuracy of *repetition,* as previously entioned, is within 0.0002″—a maxi-um variability from workpiece to orkpiece due to the overall character-stics of the machine and of the tool s well as of the control system—but he accuracy of *surface smoothness* (the "error" of the control system roper) is such that when both tool and emplet have been properly ground and oned, the control system has operated n engine lathe to produce a surface moothness of 60 microinches as meas-red by the Brush Surface Analyzer.

OPERATION

The schematic diagram shows the ap-lication of the method to an engine athe to drive automatically both the ross-slide and the carriage. As is eas-y seen with the aid of the shadings epresenting air and oil, the contour ontrol system as a whole comprises (1) an air gaging system, (2) an air ontrol system and (3) a hydraulic ontrol system. The air control system s used as an amplifier of motion and a source of power in transmitting the ovement of the tracer stylus to the ydraulic control system.

Motion of the hydraulic pilot is from 25 to 100 times greater than that of the stylus, depending upon the rate of the spring used in the hydraulic relay valve assembly. A fully-balanced air pilot valve permits operation of the tracer stylus with from 3 to 8 ounces of force. This in turn permits the use of a soft metal templet.

The tracer design, based on the regulation of an air flow to create a back pressure, permits measurements to be made in a few thousandths of a second. It employs the same principle used in precision air measuring gages, except that it regulates the air flow by stylus position instead of by size of piece being measured. In both cases the rate of air flow indicates the measurement.

As the spring-loaded tracer follows the templet, changes in contour tend to increase or decrease the air loading pressure in the air control system by changing the rate of flow from the air pilot nozzle. Air is supplied to the system from a constant-pressure source through an orifice of the proper size to maintain the loading pressure of 35 lbs./in.^{2} when the tracer is in a neutral position. This air loading pressure actuates both the contour relay valve and the feed relay valve.

Let us first consider the contour relay valve. Here it will be noted that the air loading pressure is applied to the exterior of a flexible metal bellows which, in contracting, forces its housing against the spring until equilibrium is reached between the force of the spring and the force of the air pressure on the bellows. The bellows breathes during changes in air pressure but always is balanced in a position corresponding to the air loading pressure.

Since the oil relay valve stem is attached to the free end of the bellows, it also moves up and down with changes in air pressure and is at any moment in a position corresponding to the air loading pressure.

Let us assume that at the time the control is placed in operation, the cutting tool is not in contact with the work. Under this condition the flow from the air pilot nozzle would be decreased by the tracer and the air loading pressure would increase above its neutral value of 35 lbs./in.^{2}. The contour relay valve of the hydraulic system would move upward and open the rear portion of the cross cylinder to drain. Hydraulic pressure in the front portion of the cylinder would move the piston backward, carrying the cross-slide, tool, and tracer inward. This movement brings the stylus of the tracer into contact with the templet and increases the flow of air from the air pilot nozzle and, when the air loading pressure reaches its neutral value of 35 lbs., movement of the cross-slide stops. At the neutral air loading pressure of 35 lbs. the contour relay valve has returned to its neutral position as shown in the diagram and has locked the cross-slide in a fixed position by applying hydraulic pressure equally to both sides of the power cylinder.

In actual operation the air loading pressure does not vary appreciably from the 35-lb. neutral since any tendency to depart from this pressure causes almost instantaneous movement of the cross-slide in the direction required to restore the neutral loading pressure.

The rate of longitudinal feed is controlled by the feed relay valve which in effect throttles the oil drain from the longitudinal power cylinder in accordance with changes in air loading pressure. The maximum rate of drain from the cylinder and consequently the maximum rate of feed occurs when the air loading pressure is at the 35-lb. neutral. Either an increase or a decrease in air loading pressure from this value decreases the rate of feed. In fact, if the deviation from the neutral air loading pressure is sufficient, longitudinal feed is stopped altogether. Such a condition exists when facing a square shoulder.

APPLICATION

While the possibilities of applying this new method to various machine tools are bounded only by the imagination, its use at the present time is being limited to lathes and vertical boring mills. The photograph shows its application to a 12″ Hendey lathe. The essentials are: a sturdy templet support rack rigidly fastened to the lathe bed; a pneumatic tracer held by a rigid arm securely attached to the lathe cross-slide; cross and longitudinal power cylinders, both attached to the lathe carriage; hand controls within reach of the operator's right hand; a control power unit which rides back and forth on a monorail track with the

(Continued on page 304)

Viscous Fluid Flow through a Small Orifice

[The original article (by William Jones and Otto Lutherer) and one discussion (by M. F. Behar) appeared in *Instruments,* Dec. 1943, pages 728-729]

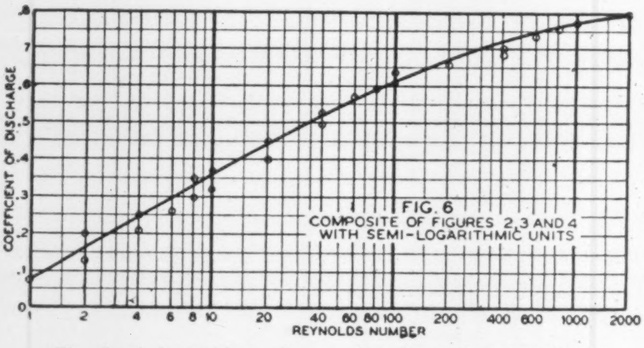


Fig. 6. of the article by Jones and Lutherer (here reproduced smaller) summarizing the results of their tests.

FURTHER DISCUSSIONS

By R. E. SPRENKLE, Bailey Meter Co., Cleveland, Ohio

The data presented by Messrs. Jones and Lutherer on the characteristics of viscous flow through small orifices are indeed welcome. Industry could well use similar data from many more such projects, since the total knowledge on this subject is rather meager.

The usefulness of the data in this paper would have been enhanced considerably had the data been given in more detail. First, the pipe size should have been given in addition to the orifice diameter so that the actual orifice diameter ratio could have been determined. Then the data could have been correlated with those obtained by Johnasen, Witte, Giese, Daugherty and others as was done in the paper* by Tuve and Sprenkle referred to in the beginning of the Jones and Lutherer article.

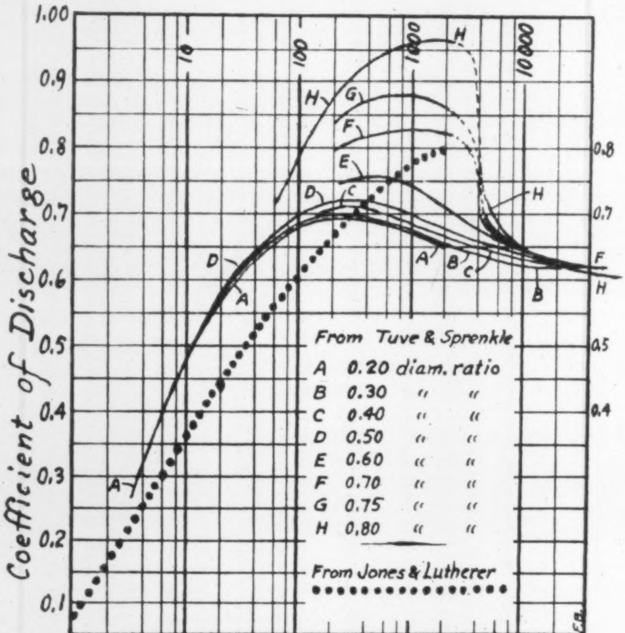


Fig. 9. This is a combination for the benefit of readers who do not have easy access to the Nov. 1933 *Instruments* in which the article by Tuve and Sprenkle was published. This illustration is of course much smaller than Fig. 6 of the article by Tuve and Sprenkle, which included many fine details and showed hundreds of actual test points obtained with heavy motor oil, light motor oil, light paraffine oil, and water. Note that the orifices used by Tuve and Sprenkle ranged from 0.255" to 1.018" and that Jones and Lutherer investigated one extremely small (0.03") orifice.

While the general shape of the curves given by Messrs Jones and Lutherer conforms to those given in the Tuve Sprenkle paper for Reynolds numbers from 0 to 300, i does not so conform at higher Reynolds number. Perhap this may be due in part to the fact that in the Jones an Lutherer tests the maximum Reynolds number never exceeded 2000 (actually there were but 9 to 10 test point above Reynolds number of 1000). It is believed that ha more data been taken at higher Reynolds numbers a dro in the coefficient of discharge curves may have been mor evident. In fact, such a decrease in the value of coefficien of discharge actually does occur with standard thin-plat orifices of approved shape as the flow passes from th viscous to the normally turbulent regions as will be note in Fig. 6 of the Tuve-Sprenkle paper. [Ed. Note—Se Fig. 9 herewith.]

Another possible reason for this lack of complete correlation is the violation of the physical proportions of th orifice hole with the requirement of the diameter of th orifice hole being equal to at least eight times its width as brought out by M. F. Behar in his discussion.

It would also have been well to have described the condition of the inside surface of the pipe or pipes in whic these orifices were tested. Pipe roughness is of larg moment when the pipes are small in diameter, and affect the coefficient of discharge appreciably. Therefore, it i advisable that such small pipes be of smooth bore and o uniform cross-sectional area, at least in the immediat vicinity of the orifice plate location.

The orifice edge sharpness is an additional most important point, especially in such small orifices. The inlet edg must be sharp and square, and must not appreciably reflec light. A statement of whether the outlet side of the orific hole was bevelled or not—and if bevelled, the details a to the proportions used—would also have been desirable

---

*G. L. Tuve and R. E. Sprenkle, "Orifice Discharge Coefficient for Viscous Liquids." *Instruments*, Vol. 6, Nov. 1933, pages 201-20

By S. R. BEITLER, Assoc. Prof. Hydraulic Engineering
Ohio State University, Columbus, Ohio

The article by Messrs. Jones and Lutherer is a ver interesting addition to the literature of the flow throug orifices, and certainly is the first published data that know of where oil has been used for flow through smal

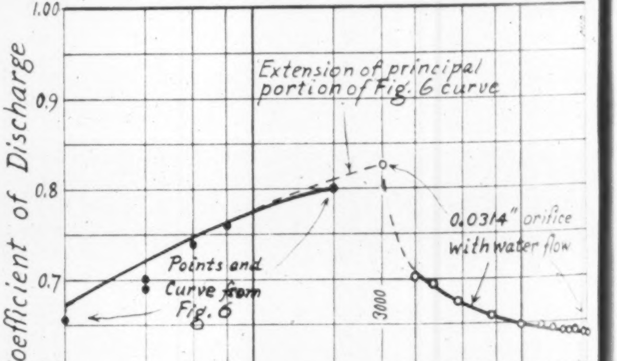


Fig. 10. Tracing from graph accompanying Professor Beitler's discussion, with one alteration by the editor. This alteration (authorized by Professor Beitler) affects only the portion between R=1000 and R=3000. It consisted in (a) drawing this part as a dotted line instead of a solid line and labeling it "extension"; (b) showing the Jones and Lutherer Fig, 6 test points; (c) drawing as a solid line the portion between R=1000 and R=2000 and keeping its shape and position. (NOTE—It is between R=2000 and R=4000 that flow in a pipe line changes from viscous to turbulent.)

orifices. The only preceding publication on orifices of this size is in a paper by Mr. H. J. I. Bilton in *Proceedings of the Victorian Institute of Engineers* (Australia) in 1908.

In 1925, Mr. (now Professor) R. S. Howell of the Georgia Institute of Technology, conducted an investigation into the flow of water through small orifices in connection with his master's thesis. A copy of this is available to the writer, and one of the orifices tested had an actual diameter of 0.0314", which makes it approximately the same as the one tested by Jones and Lutherer. This orifice was in a plate approximately 0.022" thick, so that the results from its calibration should give coefficients comparable with those presented in the article under discussion.

With this in mind I have taken the data from the authors' Fig. 6 and plotted points from Professor Howell's thesis on the same curve, with extremely interesting results. [See Fig. 10.] It will be seen that one of the points for water falls almost exactly on the extension of the curve for the oil orifices. This point was for a Reynolds number of about 3,000. There is then a sudden break, the coefficient falling very rapidly, so that at a Reynolds number of 4,000 the coefficient is dropped about 30%. This would seem to indicate, first, that the two orifices were comparable and, second, that the work done by the authors was entirely in the streamline flow region.

In Major Behar's discussion he has pointed out that the curves given in Figs. 2, 3 and 4 do not have the same shape. However, if all of the points are plotted, I think it would be found that an average curve could be drawn through the various data which would be as accurate as the individual curves. This brings out the fact that it is very difficult to decide on the shape of a curve when a relatively large number of points are available and when the curve follows no definite mathematical shape.

Experience in working with orifices using oil has shown that it is rather difficult to repeat tests and get consistent data. The authors' curves indicate this, since there is a spread of approximately 6% to 8% between data taken at about the same Reynolds number. This is especially true when using petroleum products, since there may be some lack of homogeneity in the material at various times. If this is taken into account, it can be seen that the spread between individual curves is within the limits of the experimental error of the data, and it would be difficult to predict the behavior of an orifice of this size with the information now available to much closer than ±5%.

Considerable additional work must be done to determine the effects of some of the variables such as orifice thickness, orifice edge condition, approach roughness, etc., before it will be possible to accurately predict coefficients for small orifices.

AUTHORS' CLOSURE

By WILLIAM JONES and OTTO LUTHERER

The able discussions of Messrs. Behar, Beitler and Sprenkle point out the necessity of elaborating on three points, namely:

1. The orifice characteristics.
2. The interpretation of the data as to the composite curve obtained.
3. The purpose for which the data were obtained.

1. Fig. 11 shows the orifice plate and the block in which it was mounted. The design was made so as to include a clean-out feature which consists of a drill the same size as the orifice, mounted on a movable shaft and placed concentric with the orifice.

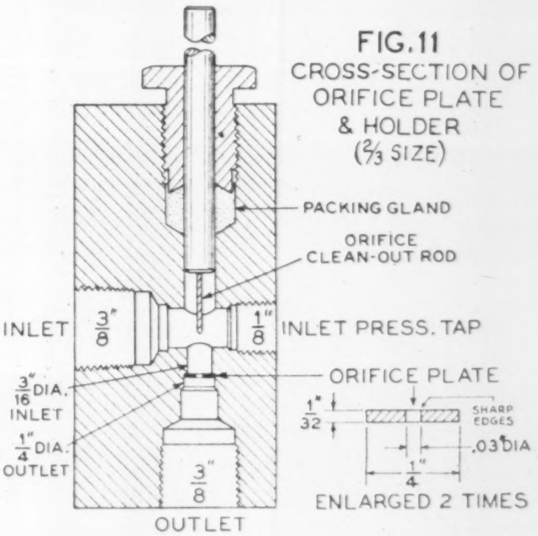


FIG. 11
CROSS-SECTION OF ORIFICE PLATE & HOLDER (2/3 SIZE)

2. The three curves shown in the original articles as Figs. 2, 3 and 4, which correlate the data for the individual oils used, have been redrawn in Fig. 12 and are shown so as to present the data in a different form. Each original curve is shown here as three curves, the difference between the curves being due to a different pressure drop across the orifice, and the difference between the points on any one curve being due to a different oil viscosity. This method of presentation of the data seems to bear out S. R. Beitler's conclusions concerning data consistency.

3. Although it would be advantageous to obtain results which would be of value in metering fluids, the authors did not have this in mind when the work was started. The main idea was not primarily to determine the actual flow coefficient but to determine the trend or change in the coefficient as more or less oil was put through a valve or orifice by changing the pressure drop. For this reason, no special attention was given to the orifice characteristics except to make it measurable and thereby be able to determine Reynolds Numbers for correlation purposes, which would not be possible with an ordinary valve.

The authors wish to thank Messrs. Behar, Beitler and Sprenkle for their enlightening discussions and constructive criticisms.

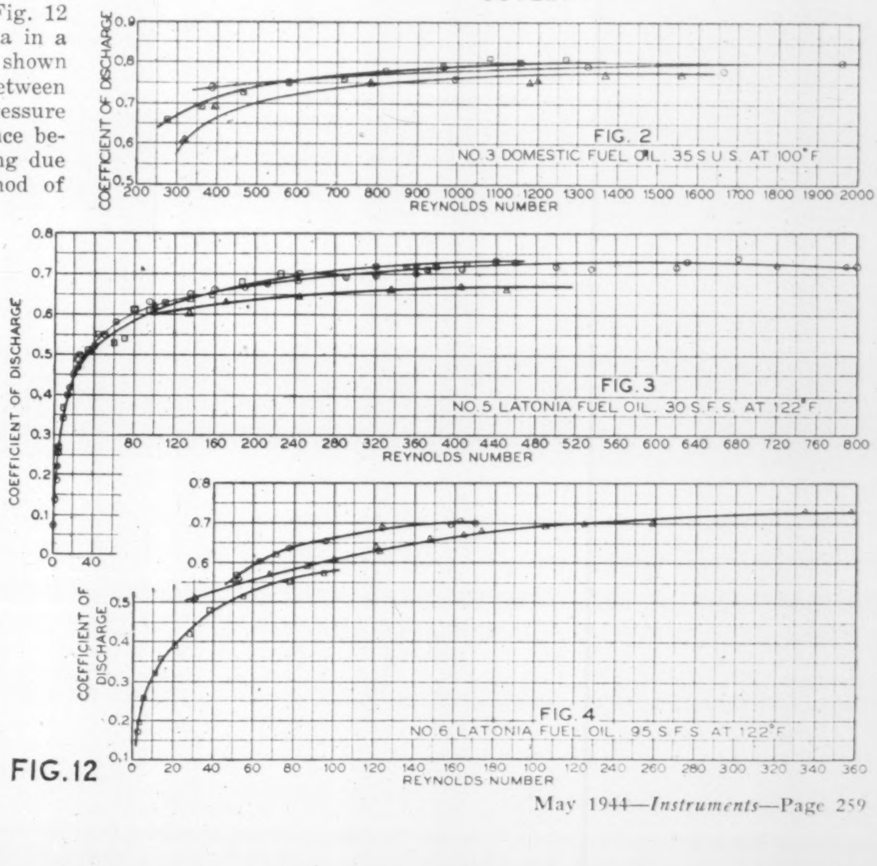


FIG. 12

ELECTRIC GAGING METHODS for Strain, Movement, Pressure and Vibration

By HOWARD C. ROBERTS, University of Illinois

CHAPTER III
GAGING METHODS BASED ON VARIATIONS OF CAPACITANCE

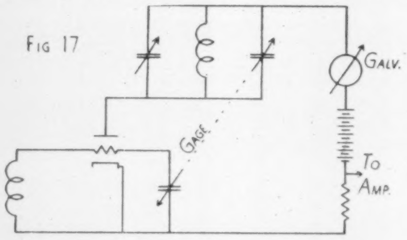
ELECTRIC CIRCUITS
(Concluded)

All of the previously-described circuits have been applied to gaging elements of the two-plate type. This pick-up has the disadvantage of non-linearity of response when used with the circuits described; and this non-linearity becomes more pronounced as the spacing of the plates is made closer. Yet, for many applications, the plate spacing must be made small in order to provide sufficient sensitivity. Certain types of installations (pressure measurement in particular) are most easily made with the two-plate pick-up; for this reason there is still a demand for improved circuits.

An examination of the curves previously presented (see Figs. 2A and 2C) will show that it is not convenient to measure large movements with a two-plate capacitance-type pick-up, unless it is of the variable-area type. With the three-plate push-pull type, however, relatively large movements can be measured and recorded without serious distortion or the need for elaborate shielding. The balanced nature of the pick-up facilitates its installation, so that although its impedance is extremely high, difficulties arising from that source can be eliminated. For example "body capacitance" due to approach of operator's hand during adjustment causes no difficulty in such a balanced circuit.

The first such circuit was a simple modification of the Whiddington ultramicrometer; two similar but opposing pick-ups were used, so connected electrically that the movement being measured caused an increase in the frequency of oscillation of one electric circuit and a corresponding decrease in the frequency of the other. The sensitivity of the system was thereby doubled; at the same time, since both circuits are similar and similarly treated, drift was reduced and stability and accuracy improved.[21] Several circuits of this type have been used; they do not differ in principle.

FIG 17



Another such system, employing only one electron tube but with two frequency-responsive circuits, appears in Fig. 17. The indicating device shown is a galvanometer, but the output can if desired be recorded with any suitable graphic instrument. Further amplification may be supplied if needed.[22,23] The circuit design is such that the pick-up must embody four electrode plates, only one of which is connected to ground. Shielding of the pick-up is required.

Using Fig. 10 as a basis, a circuit employing a three-plate pick-up with the central movable plate grounded can be set up; it is necessary only to place one of the two gage capacitances in each of the two oscillating circuits. It is convenient to provide small variable capacitors, in parallel with the gage capacitances, for adjustment purposes. A number of circuits of this type have been used; their advantages over that of Fig. 17 are greater ease of construction and provision for balancing out the steady component of the anode current of the electron tube. These circuits are essentially tuned-plate tuned-grid oscillators.

A distinct type of circuit, unique in that it takes advantage of the coupling between two synchronized oscillating networks, is the Schaffer circuit. In this circuit the synchronizing current flowing in the coupling network is the criterion of change.[24,25,26] Its operating principle deserves detailed description.

If two oscillating circuits operating at exactly the same frequency and in the same phase are coupled by an inductive circuit, no current will flow through the coupling circuit. But if the frequency of one changes, the first result will be a difference in phase, and current will immediately flow through the coupling circuit; if the coupling is close, this current will act to keep both circuits oscillating at the same frequency, although their natural frequencies will not be the same. The two circuits are then "locked-in" with each other. In this condition, the phase difference is a measure of the difference of the tuning of the two circuits, and the coupling current is proportional to this phase difference. The high-frequency current flowing through the coupling circuit may be rectified, filtered, and read on a suitable instrument.

In Fig. 18 is shown the basic diagram of such a circuit. Either a two-plate or a three-plate pick-up may be used; or two separate pick-ups, if the summation of their outputs is desired. In this diagram, the inductive coupling coils are indicated by L_1 and L_2; the coupling current is rectified by the rectifying tube V_1, and the resulting direct current is measured by the indicator G. This instrument is shunted by capacitance C_3 so that the impedance to the flow of high-frequency current is low; the internal capacitance of the diode V_1 serves the same purpose. Since the coupling circuit is of low impedance, large currents can flow; G may be an insensitive milliammeter. The gage capacitances are indicated as C_1 and C_2. The circuit is normally operated at a convenient radio frequency; 5 to 10 megacycles has been found satisfactory. Without any filtering other than that provided by the ordinary circuit components, good traces have been obtained on magnetic oscillographs recording up to 2500 cycles per second; even though not all the carrier frequency was filtered out, what remained was ineffective in operating the galvanometers, so that the rectified current was all that was recorded. The high carrier frequency makes possible the effective use of the circuit for recording high-frequency phenomena; the upper limit of usable frequency response may be considered to be 20 percent of the carrier

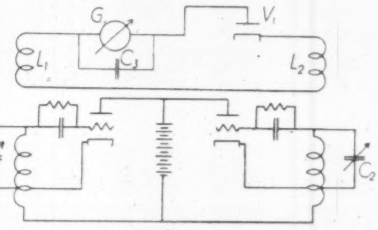


FIG. 18

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(21) R. Whiddington and F. A. Long. Application of the Ultramicrometer to the Microbalance. *Philosophical Magazine,* series 6, Vol. 49, 1925, pages 113-121.

(22) F. de la Chard. Application of Thermionic Valve to the Measurement of Physical Quantities. *Journal of Scientific Instruments* (London), Vol. 12, 1935, pages 191-194.

(23) F. de la Chard. Electrical Recording Extensometer. *Engineering* (London), Vol. 136, 1933, pages 699-700.

(24) Walter Schaffer. Amplifier. U. S. Patent No. 1,717,630. June 18, 1929.

(25) F. W. Lee and G. A. Irland. Construction of Master Mechanical Oscillator for Testing Seismic Recorder and other Apparatus. *Bureau of Mines Technical Paper No. 518,* 1932.

(26) E. V. Potter. An Electrical Transducer Circuit for Use With Capacity Pick-up Devices. *Review of Scientific Instruments,* Vol. 14, 1943, pages 130-135.

frequency or the upper limit of the gage or recording device, whichever is the lower.

This type of transducing circuit is one of the most reliable, stable and accurate available. It employs only three electron tubes, and these are inexpensive radio receiving-set types. It responds faithfully to phenomena whose frequencies range from static conditions to thousands of cycles per second. Its demands upon the power supply are not excessive, either in wattage or as to degree of regulation. It requires little or no shielding and few precautions in installation. A practical circuit for the transducer is shown in Fig. 19, and in Fig. 20 a set of curves indicating performance under typical conditions. Details of construction may be found in the references.

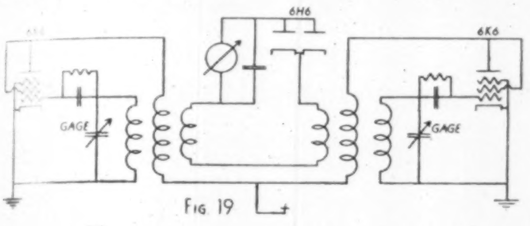

FIG 19

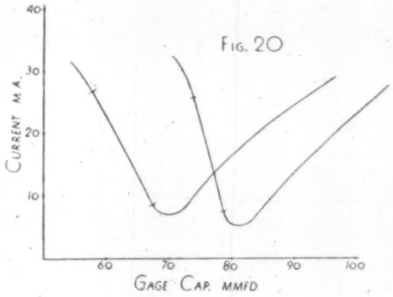

FIG. 20

Among the special-purpose circuits, two types in particular merit attention. They are the absorption-type electric gaging circuits, and the capacitance-type altimeter.

The operation of an absorption-type circuit depends upon the fact that any closed coil will absorb energy from an oscillating circuit to which it is coupled; the amount of energy absorbed will depend upon the accuracy of tuning, and upon the closeness of coupling. The energy lost by absorption is supplied by increase in the anode current of the oscillating electron tube. Superficially, the absorption-type circuit resembles those circuits in which a change in oscillator frequency causes a change in anode current; actually its action is entirely different.

One of these absorption circuits was designed specifically for installation in inaccessible locations, as, for example, imbedded within a concrete structure.[27,28] Its gaging element is a two-plate capacitance-type pick-up, which may be cast within the body of the concrete. After the concrete has set and has been cured, the circuit may be adjusted for subsequent use; thus, curing strains will not destroy the utility of the gaging element for sensitive measurements at a later date. This circuit is shown as Fig. 21A. It may be used to measure small strains, by allowing the strain to change the capacitance of the gaging element; or it may be used to measure movements, by allowing the movement to change the electromagnetic coupling between the two tuned circuits.

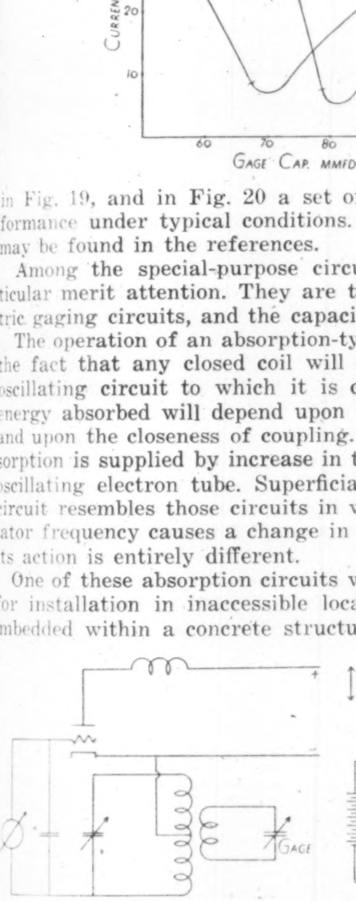

FIG. 21A

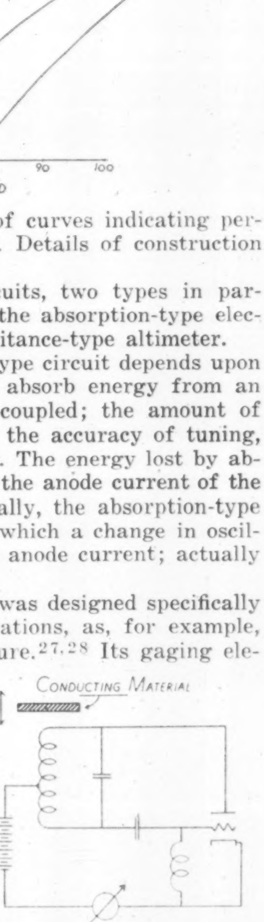

FIG. 21B

The other basic absorption-type circuit does not employ a tuned resonant circuit as an absorption circuit; instead it uses a metallic plate, or a metallic part of the structure, as an absorption element. Such a metallic part, although not a resonant circuit, will absorb energy from the oscillating circuit (see Fig. 21B), and the amount of energy absorbed will vary inversely as the distance separating them. The change in anode current will therefore indicate the change in the distance separating the oscillator coil and the metallic absorption plate.[29,30] A high oscillation frequency is used, and the absorbing member may be a thin piece of metal foil, attached to the surface of a non-metallic member. The circuit is easily adapted to use as a pressure pick-up.[31] In another form, the coil is surrounded by a split metallic sleeve, which acts as a capacitative element.

The capacitance-type altimeter is another device which measures distance, not between two parts of the gaging element, but between the gaging element and some other object. In this case, the measurement is of the distance separating an aircraft from the ground beneath it. An extremely sensitive circuit is required; such a circuit is shown in Fig. 22. The two differentially-wound inductors, L_1 and L_2, are tuned to resonance by the capacitances C_1 and C_2; when they are so tuned no potential is induced across L_3. The capacitance between the pick-up and the earth appears in parallel with C_2. The effect of this capacitance is to detune the circuit, so that a voltage is induced in L_3. This voltage is measured by the vacuum-tube voltmeter. The circuit is excited by a radio-frequency oscillator.[32,33,34]

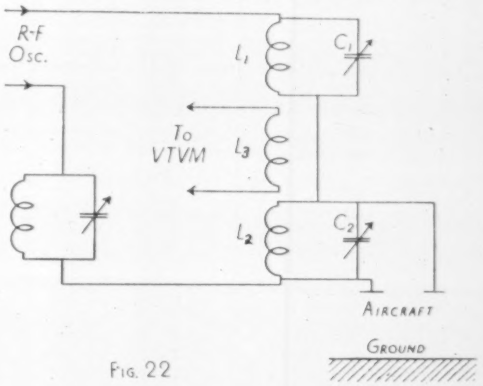

FIG. 22

The circuits which have been described thus far are not well suited for multi-channel operation, which is a disadvantage because the need for simultaneous multi-point recording grows constantly. The circuits which will now be described are applicable to multi-channel installations. They do not employ the gaging element as part of a frequency-responsive network in an oscillating electrical circuit, nor do they depend upon critical coupling values. Instead, the gaging element is made an impedance element in a circuit which is excited by some constant frequency. Since only one exciting frequency is present, no matter how many measuring channels are in operation, interaction between circuits is less likely than in the circuits in which variable and varying carrier frequencies are used.

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(27) A. Floris. New Instrument Measures Stresses in Dams. *West Construction News*, Vol. 7, 1932, pages 51-52.

(28) Paul Santos Rini. Experimentelle Ermittlung von Spannungsdifferenzen im Innern einer gleichartigen Masse (ins besondere Beton) und Verformungsmessungen an belasteten Baugliedern mittels hochfrequenter elektrischer Wellen. ***Beton und Eisen***, Vol. 22, 1930, pages 411-413.

(29) H. A. Thomas. Precision Measuring Instruments for Small Motions of Solid Bodies. *The Engineer* (London), Vol. 135, 1923, pages 138-140.

(30) E. B. Moullin. Report on the Thomas Gauge. *Report of the Bridge Stress Committee*, His Majesty's Stationery Offices, 1928. Appendix G: pages 193-198.

(31) W. Marti. Registrierung schneller Bewegungen. *Schweizerische Bauzeitung*, Vol. 104, 1934, page 160.

(32) L. A. Hyland. True Altitude Meters. *Aviation*, Vol. 25, 1928, pages 1322-1323, 1356, 1358, 1360, 1362.

(33) Ross Gunn. Device for Indicating Small Changes in Capacity. U. S. Patent No. 1,701,975. Feb. 12, 1929.

(34) G. Falkenberg. Ein Differentialschaltung zur Messung von Kapazitaten und Selbstinduktionen mit einer Empfindlichkeit von 2×10^{-8}. ***Annalen der Physik***, Vol. 61, 1920, pages 167-172.

In these circuits, some exciting current or voltage must be used. This exciting voltage may be either direct or alternating. Each has its advantages. In many respects, d-c. excitation is more satisfactory than a.c. for high-frequency measurements; however, a.c. can be used, and for the lowest frequencies must be.

The "condenser-microphone circuit" is representative of those employing d-c. excitation. The capacitor microphone is a two-plate pressure pick-up having sensitivity sufficient to measure acoustic pressure waves, and responsive to frequencies as high as 10,000 cycles per second. The elementary circuit used with the device is shown in Fig. 23. In this circuit the output voltage, V, can be computed from the relation

$$V = E\ (x/x_0)\ \sin(2\pi t + \phi)$$

where E represents the exciting voltage, and the other terms represent the change in capacitance caused by a sinusoidal pressure wave.[35] It is assumed that the charging resistor R is large compared to the impedance of the pick-up. Since the impedance (the capacitative reactance) of a capacitor increases as the frequency involved decreases, the lower limit of frequency response is dictated by the value of R. Values of R greater than about 20 megohms are difficult to maintain in practice, so that for recording extremely low frequencies other systems are ordinarily employed.

This simple d-c. excited circuit has been widely used for frequencies ranging from 50 to about 8,000 cycles per second. Its most serious limitations, within this range, are due to the effects of the connecting cable. If this cable is long, its capacitance, shunting that of the pick-up, causes a uniform reduction in sensitivity. Insulation leakage, however, causes a loss in sensitivity which is greater for the low than for the high frequencies. Vibration and other mechanical phenomena may cause the cable itself to act as a pick-up. Capacitance-type gaging systems operating on this principle are easily applied as engine indicators; the lack of extremely low frequency response may even be an advantage since it eliminates drift from the recorded output. Where short cables can be used, such pick-ups are effectively used.[36] They have also been used to good effect to measure and record the action of the injector valves of Diesel motors;[37] the record thus produced was arranged to show the variation of volume of fuel injected against time. The capacitor microphone has been used to measure noise levels in motors[38] and for many other applications.

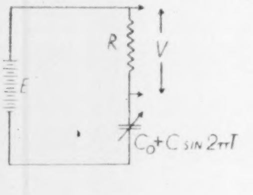

Fig. 23

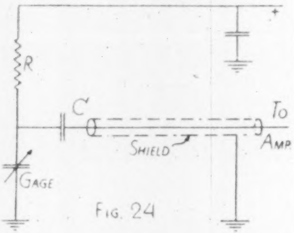

Fig. 24

A modification of the basic circuit which will greatly reduce these errors (at the cost of some sensitivity) appears in Fig. 24. Capacitance C' should be small for good correction, but if too small will reduce the sensitivity to the point where it will be difficult to provide sufficient amplification.[39]

Other circuits based on this principle have also been used. In these circuits, the three-plate pick-up offers little advantage over the two-plate type.

OUTLINE OF "ELECTRIC GAGING METHODS"

Part One—Principles of Operation.
    Chapter I. Introduction.
    Chapter II. General Principles.
    Chapter III. Capacitance-type Gages.
    Chapter IV. Inductance-type Gages.
    Chapter V. Resistance-type Gages.
    Chapter VI. Miscellaneous Types of Gages.
Part Two—Auxiliary Circuits and Recording Devices.
    Chapter VII. Indicators and Recorders.
    Chapter VIII. Power-supply Equipment.
    Chapter IX. Computing Devices.
Part Three—Operating Techniques.
    Chapter X. Methods of Application.
    Chapter XI. Calibrating Methods.
    Chapter XII. Errors in Actual Use.

Individuals, companies and institutions having information on little-known methods, or on novel and useful applications of well-known methods, are invited to communicate directly with the author: H. C. Roberts, 108 Talbot Laboratory, Urbana, Illinois.

The simplest of the a-c. excited circuits is shown in Fig. 25. This device has been applied in multi-channel installations in industrial locations.[40] A radio-frequency oscillator is closely coupled into a circuit which is tuned to nearly the frequency of the oscillator. The circulating current in this circuit then depends upon the voltage induced in the coil L, the tuning, and the circuit constants. This circulating current is measured with the radio-frequency ammeter, M. In such a circuit, the current flowing may be computed from this formula:

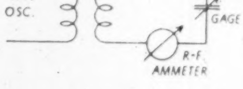

Fig. 25

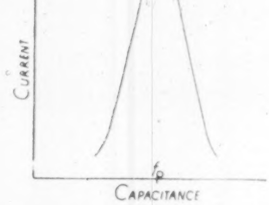

Fig. 26

$$I = \frac{E}{\left[R^2 + \left(2\pi f L - \frac{1}{2\pi f C}\right)^2\right]^{1/2}}$$

where I represents current in amperes, E potential in volts, R resistance in ohms, C capacitance in farads, L inductance in henries, and f the frequency of excitation in cycles per second. The applied voltage is that induced across the inductor, and is constant. The circulating current then varies with the gage capacitance in the manner plotted in Fig. 26. The steep, essentially linear portion of this curve defines the operating range. By increasing the ratio of impedance to ohmic resistance (the Q) of the coil, the resonance peak may be made steeper and higher; increasing the ratio L/C has the same effect. If a coil having a Q of 100 is employed, it is not difficult to provide a pointer indication a million times as great as the movement at the gage head. Greatest sensitivity for small movements is secured by operating on the straight part of the resonance curve. If large movements are to be measured, non-linearity may occur in the gaging element (see Fig. 2A) but may be compensated by operating on the oppositely curved portion of the resonance curve. Satisfactory operation of this circuit depends principally upon its design; it is necessary that the proper L/C ratio be selected, that the ohmic resistance of the circuit remain constant, and that the exciting oscillator maintain constant output.

Gaging devices operating on this principle have been used as multi-point station-type comparators, for measuring the thicknesses of moving webs, and for other applications.[5,40]

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(35) E. C. Wente. A Condenser Transmitter as a Uniformly Sensitive Instrument for Absolute Measurement of Sound Intensity. *Physical Review*, Vol. 10, 1917, pages 39-63.

(36) G. N. Copley. Cathode-ray Oscillograph Indicator. *Industrial Chemist*, Vol. 18, 1942, pages 89 to 92.

(37) C. R. Maxwell and K. M. Brown. Instrumentation for Developing and Testing Diesel Engines. *Transactions of the American Society of Mechanical Engineers*, Vol. 64, 1942, pages 351-361.

(38) J. H. Hunt and G. F. Embshoff. Some New Electrical Instruments for Automotive Research. *Journal of the Society of Automotive Engineers*, Vol. 16, 1925, pages 444-455.

(39) F. D. Smith. Basic Principles in the Design of Cathode-ray Oscillograph Engine Indicators. *Proceedings of the Institute of Mechanical Engineers*, Vol. 143, 1940, pages 48-56.

(40) H. Olken. Industrial Process Control. *Electronics*, Vol. 3, 1931, pages 144-145, 172.

Some of the most satisfactory circuits have been those in which the gaging element is made an impedance element in a bridge circuit. Such a circuit, if it is balanced to zero output for the static condition, can provide for reasonable degrees of unbalance output voltage proportional to capacity change. The output of the bridge is amplified and recorded by a graphic instrument, or indicated upon a pointer-type indicating instrument.

Of the several types of capacitance bridge circuits in common use, the Schering circuit is the most desirable for precise measurement of small capacitances; it is therefore best adapted for use with capacitance-type gages. The circuit has been used with good results for measuring small mechanical movements and for recording cutting pressures of machine tools.[41] The circuit, shown in Fig. 27, is a form of Schering bridge; its output is applied to the control grid of an electron tube amplifier. If the bias voltage is properly selected, the variations in anode current of the tube are proportional to the changes in capacitance of the gaging element. Since both resistance and capacitance balances are possible, cable capacitance and cable leakage can both be compensated to some extent. The circuit can be excited by any desired frequency; therefore if radio-frequency excitation is used, the circuit can follow the most rapidly changing mechanical magnitudes.

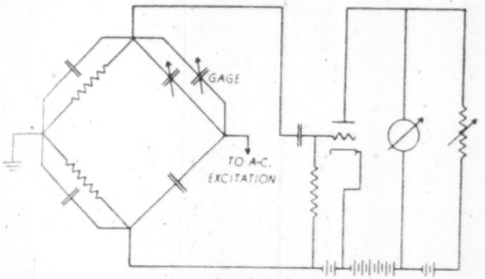

FIG. 27

A circuit in which the two variable capacitances of a three-plate push-pull pick-up comprise two arms of a bridge circuit is diagrammed in Fig. 28. In this circuit the other arms of the bridge circuit are fixed resistances; in a modification of the circuit the other two arms are the impedances of the two halves of a center-tapped transformer which supplies the alternating-current excitation.[42, 43, 44] Circuits of this type are exceptionally stable, by reason of their balanced design, and in them compensation can be provided for the effects of temperature, age, and other sources of drift. Since they incorporate electronic amplification, they can record their data on an oscillograph or indicate it on a suitable indicating instrument. Such an installation has been used to measure and to record continuously the diameter of silk thread.[45] The basic circuit was similar to that shown in Fig. 28. A two-plate pick-up was used; since the atmospheric conditions were controlled, and since the range of measurement was small, the advantages of the three-plate type were negligible. The balanced circuit was found extremely reliable. The output of the circuit was applied to an indicator, to a recorder directly and through an integrating device, and even to thyratron control devices.

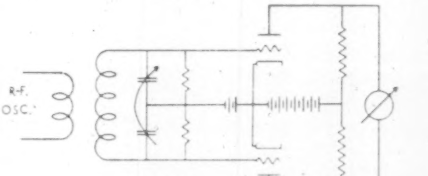

FIG. 28

In order to eliminate the errors caused by cable capacitance, circuits have been designed in which this capacitance is made a part of the bridge circuit. By the use of three-conductor concentric cable and the circuit of Fig. 29, excited by a 100-kc. carrier frequency, the effects of shock and vibration on the cable, and loss of sensitivity due to its shunting effects are reduced to negligible magnitudes.[46] In this circuit, C_1 and C_2 are known capacitances installed inside the case of the instrument, R_2 is a phase-correcting resistance, R_1 a sensitivity control, C_3 the capacitance between the central conductor of the cable and its surrounding internal shield, and C_4 the capacitance between this and the outer shield, which is connected to the common ground. The output of the bridge circuit is amplified and recorded; it can give good results from the lowest frequencies up to the upper limit of response of the magnetic oscillograph or up to about 20% of the excitation frequency, whichever is lower. The balancing procedure allows satisfactory use of quite long cables.

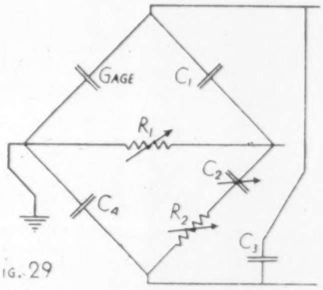

FIG. 29

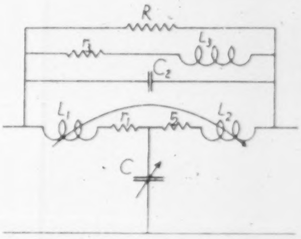

FIG. 30

Another and more recent circuit which also provides for balancing out the cable capacitance but can be set up with ordinary shielded cable, is shown in Fig. 30. It is a parallel bridged-T circuit, and requires that the two inductors L_1 and L_2 be built within the pick-up itself. The capacitance of the gaging element is represented by C. The stray capacitance of the cable and its circuit is indicated by C_2, and L_3 is an inductance introduced to resonate with this stray capacitance. Resistances r_1, r_2 and r_3 are the ohmic resistances of the inductances. If the circuit is balanced initially for the 5-megacycle carrier frequency, any changes then occurring in the capacitance C will modulate the carrier frequency and this amplitude-modulated wave can be recorded. A complete analysis of the circuit indicates its satisfactory characteristics for recording pressures from static conditions up to frequencies comparable to the mechanical resonant frequency of the metal diaphragm of the pick-up.[47] The output may be integrated or differentiated if desired. Although originally designed as an engine indicator, it can be applied to any other use in which the phenomenon being observed can be made to appear as a change in a known capacitance.

The capacitance-type gaging element has been applied in circuits in which it serves merely as a valve to control the amount of energy applied to the input of an amplifier.[48, 49] Such a circuit, although requiring more equipment per gaging circuit than most others, can be given great sensitivity and large output simply by adding amplification.

A special type of three-plate pick-up, in which one pair of plates serves to compensate errors from atmospheric changes while the other pair performs the measurement, has been used as a measuring and control device.[50] In the

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(41) A. Schulz and G. Zickner. Selbstaetiges Aufzeichnen von Arbeitsvorgaengen. *Zeitschrift Verein deutsche Ingenieure*, Vol. 74, 1930, pages 1359-1362.

(42) S. Reisch. Ueber eine neue elektrische Enrichtung zur Messung Kleiner Verscheibungen. *Zeitschrift fuer Hochfrequenztechnik*. Vol. 38, 1931, pages 101-111.

(43) S. Reisch. Ueber ein neues Galvanometerrelais. *Zeitschrift fuer Technische Physik*, Vol. 12, 1931, pages 541-549.

(44) C. W. Fieber. Elektrischer Indikator fuer schnellaufende Brennkraftmaschinen. *Zeitschrift Verein deutsche Ingenieure*, Vol. 79, 1935, pages 1368-1369.

(45) D. Hugo Schuck. Electrical Measurement of Silk Thread Diameter. *Electrical Engineering*, Vol. 55, 1936, pages 991-996.

(46) S. E. Goodal and R. B. Smith. Instantaneous Fluid-pressure Recording Equipment. *Engineering* (London), Vol. 148, 1939, pages 127-129.

(47) Louis C. Roess. A Condenser-type High-speed Engine Indicator. *Review of Scientific Instruments*, Vol. 11, 1940, pages 183-195.

(48) T. Baldwin. Communication on C.R.O. Engine Indicators. *Proceedings of the Institute of Mechanical Engineers*, Vol. 143, 1940, pages 282-284.

(49) Joseph C. Frommer. Detecting Small Mechanical Movements. *Electronics*, Vol. 16, 1943, pages 104-105.

(50) H. L. Hazen. Electrical Water-level Control and Recording Equipment for Model of Cape Cod Canal. *Electrical Engineering*, Vol. 56, 1937, pages 237-244.

application described, the liquid surface whose level is to be measured serves as one plate of the pick-up. Absence of a vertically-guided float does away with the commonest mechanical source of error, namely, friction or "stiction." The auxiliary electric circuits used with the device can record the liquid level, or both record and control it. Fig. 31 indicates the basic scheme of the measuring head. In the practical set-up, the amplifying electron tube shown in the diagram was placed within the pick-up head itself. Excitation was from the 60-cycle line current.

Attempts have been made to utilize the variations in capacitance of a gaging element to modulate the frequency of an oscillator circuit and later to analyze this frequency-modulated carrier with a discriminator circuit. As yet, circuits of this type have not proved very satisfactory for general applications, although some excellent work has been done in specialized fields.[51]

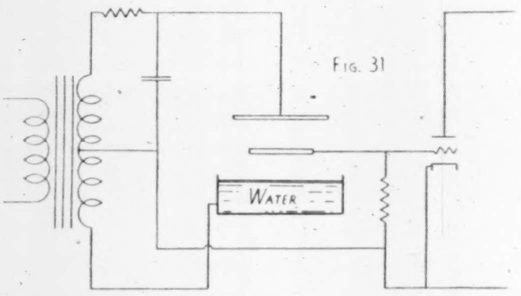

FIG. 31

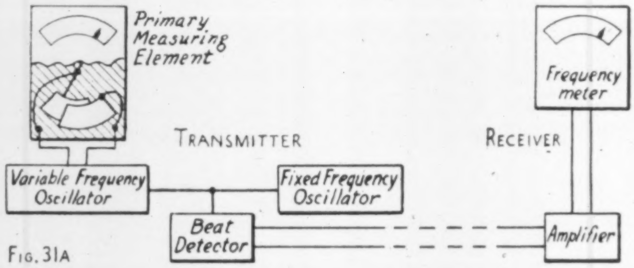
Primary Measuring Element
TRANSMITTER
RECEIVER
Frequency meter
Variable Frequency Oscillator
Fixed Frequency Oscillator
Beat Detector
Amplifier

FIG. 31A

On the other hand, notable success has been achieved in the development of practical telemetering systems embodying in the transmitter a variable-capacitance pick-up which alters the frequency of its associated oscillator according to the indications of a manometer, thermometer or other instrument; the receiver being a frequency meter of suitable type and range. The pick-up may be of the variable-area or variable-distance type, depending upon the nature of the primary instrument, and it may be made small, light and mechanically-balanced so as to impose no drag on the primary instrument's pointer or other moving part. (In some instruments the pointer needs but a slight modification to carry a featherweight capacitor plate.) The advantages and limitations of the circuits used in such systems are summarized in a discussion[52] by Borden and Behar, from which the following is quoted:

"The transmission of definitely varied frequencies over an electrical circuit is attended with certain engineering difficulties . . . Effects of inductance and capacitance are definitely related to frequency, and any problems of filtering or balancing essential to the joint use of a circuit for communication and telemetering become involved when varying frequencies are used. Since these effects are greatest at high frequencies, transmission in the radio band is often impracticable . . . These facts, coupled with the interference which would obviously be created in the use of a wide band, limit the use of radio frequencies in the practice of telemetering. Utilization of frequencies in the voice band would prevent the use of the transmitting circuits for simultaneous telephony and would be likely to introduce cross-talk troubles in neighboring telephone circuits. With these restrictions the use of varied frequencies for telemetering purposes has seldom until recently found practical application beyond the power frequency band of (say) 100 or fewer cycles per second."

Fig. 31A is a block diagram[52] of a telemetering system brought out in 1929 by the General Electric Co. which provides also for totalizing and for telemetering a number of different magnitudes over a single circuit. Another commercial telemetering system employing a variable capacitor positioned by the primary measuring instrument is the Pittsburgh Equitable Meter Co.'s "Telemco" system announced in 1935 which employs a frequency range of 36 to 60 cycles per second, the upper limit serving as a convenient check point in nearly all regions of the United States.

For telemetering by radio, instrument-actuated frequency-changing variable capacitors are particularly suitable. They have been used in various radio-telemetering systems including measurements of upper-atmosphere conditions by radiosondes, measurements of river stages for hydrographic and flood-warning services, etc.

In another system of this type, the Pioneer "Telemagnetic" aircraft compass, the indication of a magnetic compass is transmitted to a small indicator placed at any convenient location.

Capacity-actuated devices for process control are also in use. They are hardly gaging methods, since they ordinarily function simply as on-off switching devices, stimulated by the presence of some conducting body. These devices are usually of the capacity-relay type, or the grid-glow[53, 54] tube or the floating-grid relay.[55] They are used as position indicators, in follow-up mechanisms, and for process control; for example, to turn on some mechanism when an article to be treated approaches.[56] In these applications they can be used in circumstances in which photoelectric or other devices will not function.

SENSITIVENESS, SENSITIVITY, ETC.

The term sensitiveness will be used here to refer to the magnification afforded by an entire gaging system. The sensitiveness of a gaging system necessarily depends upon the characteristics of the indicating or recording instrument, of the pick-up, of the circuit, etc.

The sensitivity (strictly, the "ultimate sensitivity") of an indicating or recording instrument is the smallest change in the measured magnitude (current, frequency, etc.) which can be detected with that instrument. Sensitivity is not a function of the time required for its response to a given stimulus; it is that response. For static indications or for indications of slow changes, an instrument requiring little current can be used to measure the output of the electric circuit. Instruments recording at higher rates—having higher frequency response—require more current for their actuation. The sensitiveness of the entire gaging system therefore depends quite as much upon the current or voltage sensitivity of the indicating instrument as upon any other factor. The same system can in fact be used for static and for dynamic measurements; its sensitiveness may be many times as great for static as for dynamic measurements, because a more sensitive indicator can be employed.

The portion of a capacitance-type pick-up which converts a mechanical change into an electrical change is the gaging element. The sensitivity of the capacitative gaging element (not "ultimate sensitivity" but what is sometimes called "range," "sensibility," etc.) is a function of the percentage change in its capacitance for the smallest magnitude to be measured. This intrinsic sensitivity may be increased by decreasing the electrode spacing. (See Fig. 2C.) As this sensitivity increases, however, the distortion increases likewise. If the movement is small compared to the electrode spacing, the distortion will be negligible; if this movement is large, the electrode spacing must be made large. Increas-

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(51) Charles Sheer and John G. Lynn. Electronics in the Study of Head Injuries. *Electronics*, Vol. 17, 1944, pages 112-117, 338.

(52) Perry A. Borden and M. F. Behar. Frequency Class Telemetering Systems. *Instruments*, Vol. 8, Nov. 1935, pages 293-296.

(53) D. D. Knowles. The Theory of the Grid-glow Tube. *Electrical Journal*, Vol. 27, 1930, pages 232-236.

(54) R. W. Carson. Grid-glow Micrometer. *American Machinist*, Vol. 75, 1931, page 407.

(55) E. H. Rayner. Some Simple Experiments with Thermionic Valves. *Engineering*, Vol. 121, 1926, pages 603-604.

(56) R. A. Powers. Tubes Help Make Automobiles. *Electronics*, Vol. 9, June 1936, pages 22-24, 55.

ing the area of the plates does not increase the intrinsic sensitivity of the pick-up, but if the connecting cable has a capacitance comparable to that of the pick-up, an increase in the capacitance of the pick-up will increase the percent change in capacitance of the entire system for a given change in gage capacitance, and therefore the sensitivity.

The sensitiveness of a circuit of the Whiddington type increases as the frequency of oscillation is increased. Since two frequencies are compared, and their interference frequency is made the criterion of measurement, and since the change in the variable frequency occurs as a percentage, it is obvious that the arithmetical difference—the interference frequency—will be made larger as the oscillation frequency is made higher.

For those circuits in which the resonant increase in current or voltage in an electric circuit is the criterion of measurement, the sensitivity depends on the shape of the resonance curve. The slope of the straight sides of the curve depends primarily upon the L/C ratio of the oscillating circuit and the Q of the inductor used.

All systems employing electronic amplifiers to increase the output of the gage circuit can obviously attain any desired degree of sensitivity simply by increasing the amplification employed. The limiting factor in the amplification is reached when the noise (the random electrical disturbances in the first stages of the amplifier) ceases to be a negligible proportion of the output. It always is desirable to provide as large as possible an output from the pick-up; in this manner the signal-to-noise ratio is kept high.

The sensitivity of capacitative gaging systems is high; with such circuits it has been found possible to detect movements of only a few billionths of an inch. Few applications require this degree of sensitivity!

STABILITY

The stability of gaging systems depends primarily upon their design and construction. Since stability and accuracy are closely related, it is important to exercise great care in the design and installation of these systems.

Instability may be defined as the occurrence in the output of indications not representing actual changes in the magnitude being measured. It differs from hysteresis, from variance, and from creep, in that it may originate either in a mechanical element or in an electric circuit, and its presence does not in any manner depend on any change in the phenomenon being measured or on the extent of such change. It may be a change in a magnitude, in a condition, or in a frequency. The presence of instability does not necessarily mean that error is also present, but in general instability and error are companions. Zero drift—change in zero with time or temperature—is a form of instability; if its presence is noted and the proper precautions taken, no error will result. If the calibration of the system is accurately linear and if differences only are measured, no error will result even if the zero is not checked. Often, however, temperature changes produce simultaneous changes in zero setting and sensitiveness. In electric gaging systems, temperature drift is a troublesome type of instability.

A change in the capacitance of the gaging element will cause the same change in the output of the electric circuit whether it is produced by the phenomenon being studied or by some other. Thermal expansion of the specimen will change its length; this increase in length is an actual strain, although it is not accompanied by stress (unless the movement of the specimen is restricted). If the strain gage has the same temperature coefficient of linear expansion as the specimen and is allowed to expand with it, no strain will be indicated. But if the movement of the specimen is wholly or partially restricted, while the gage can act, the gage will then indicate a strain. Such an indication may be entirely spurious; or, if the specimen is rigidly restrained, the indicated strain will be accurately proportional to the temperature *stress* existing in the specimen. This second condition obtains when the gage and the specimen have the same coefficient of expansion, while the specimen is restrained; under these conditions no actual strain can occur. Study of the construction of an actual gaging device, as in Fig. 32, will make these statements clear.

It seldom is possible to construct a pick-up which will suffer no change in capacitance with change in temperature but by selection of suitable materials and by proper design the change can be made small. It is necessary to consider changes in linear dimension and changes in the specific inductive capacity of the dielectric, changes in area of electrodes as well as changes in their spacing. There are two general methods of attacking the problem: one is to construct a pick-up which is as nearly as possible unaffected by temperature changes; the other is to construct a pick-up which has the same temperature characteristic as the material upon which it is to be used. The requirements of the proposed application determine which of these should be used.

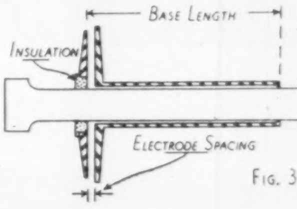
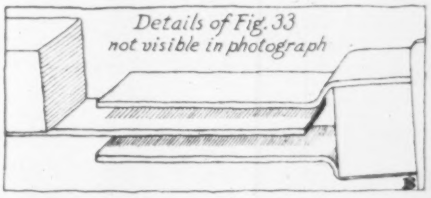


Fig. 32



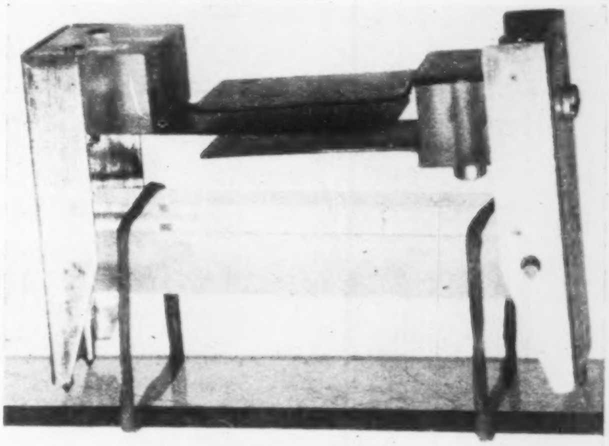


Fig. 33. Push-pull Capacitance-type Strain Gage

As an example of a device which is almost unaffected by temperature changes, consider the pressure pick-up of Fig. 3. It is constructed of materials each having a moderate temperature coefficient of expansion, but the proportions of the various parts and the manner of their assembly are such as to cause the various changes in dimension to cancel out. The actual capacitance of this pick-up varies less than 2% over the range from 70°F. to 240°F. Its calibration is therefore affected by temperature to a degree no greater than this, no matter what the use of the gage; this of course assumes that the elastic constants of the metallic diaphragm are not altered by the temperature change.[57] In use, the pick-up is applied to the measurement of changes in pressure, rather than of pressures, and is used normally in conjunction with an electric circuit which does not respond to the very slow variations of the zero point. The operating error from temperature change, therefore, can be smaller than the actual change in gage capacitance.

Fig. 33 is a photograph of a strain gage designed in accordance with the second method mentioned above. The

(Continued on page 284)

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(57) Theodore Theodorsen. Investigation of the Diaphragm-type Pressure Cell. *National Advisory Committee for Aeronautics Report No. 388*, 18 pages.

Ordnance Production Gaging

By Major R. A. BOWMAN, In Charge Gage Laboratory, Pittsburgh Ordnance District, U. S. Army

CHAPTER XI

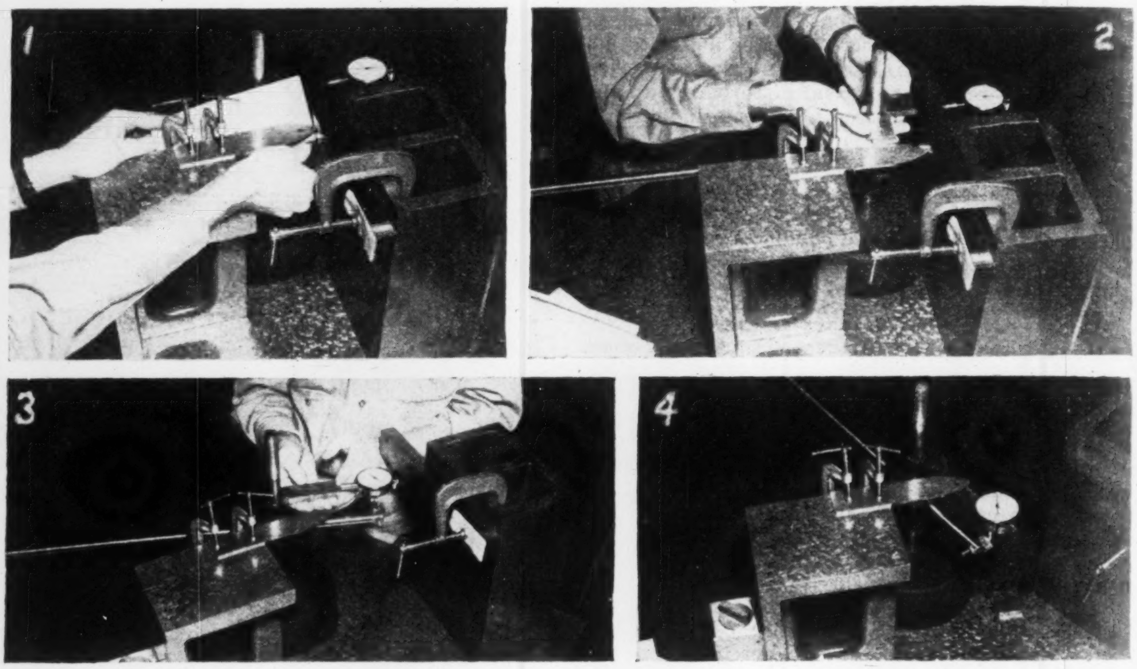
THE GAGE LABORATORY—ITS PERSONNEL

The ideal in a gage laboratory organization requires that all personnel who inspect gages be "qualified gage checkers." A "qualified gage checker" understands generally the manufacture of a gage and is capable of building the necessary setup for the inspection including:

Mathematical calculations;

Inspection of the gage for surface finish, cracks, "checking," hardness, size and functionability of parts;

Whether the gage is slightly out of tolerance (it may still be within the wear allowance, or it may be incorrect in a dimension representing a large factor of safety as in the 40% concentricity rule and still pass only acceptable material);



A series of photographs, useful for training purposes, recording the set-up and inspection of a profile gage. (1) Squaring up; (2) Measuring distance of center of standard to end of tangent of arc; (3) Mastering the indicator; (4) Indicating the profile.

The determination from an examination of the gage drawing and the component drawings of the mating parts whether or not the gage may be put back on the inspection line.

These qualifications may, perhaps, seem broad, but they are all required to make intelligent decisions as to whether or not a particular gage will pass acceptable material and reject that which is not acceptable. Certainly in a one-man laboratory, a "qualified gage checker" is required.

Obviously, at the present time, it is well-nigh impossible to find personnel with such capabilities. If the inspection load warrants several persons in the laboratory, gage inspection may be adequately performed with only one fully qualified gage checker. This is possible by breaking down the inspection problem into the several functions previously mentioned and training less qualified personnel to specialize in these functions.

For example, personnel may be trained to perform merely the routine inspection functions, having been provided with information as to the particular dimensions to be checked. As a matter of fact, even the inspection function may be broken down if the load warrants, by employing certain personnel who do nothing but inspect with the supermicrometer or comparator, others who work only on the surface plate or optical comparator, others who perform visual inspection for finish, etc. Usually, it is not feasible to break down the inspection functions on *a particular gage;* that is, have one person check the O.D., another the I.D., etc., since the dimensions on any gage are all interrelated.

More advanced personnel may be employed in designing setups and making mathematical calculations for personnel working on surface plate or optical comparator.

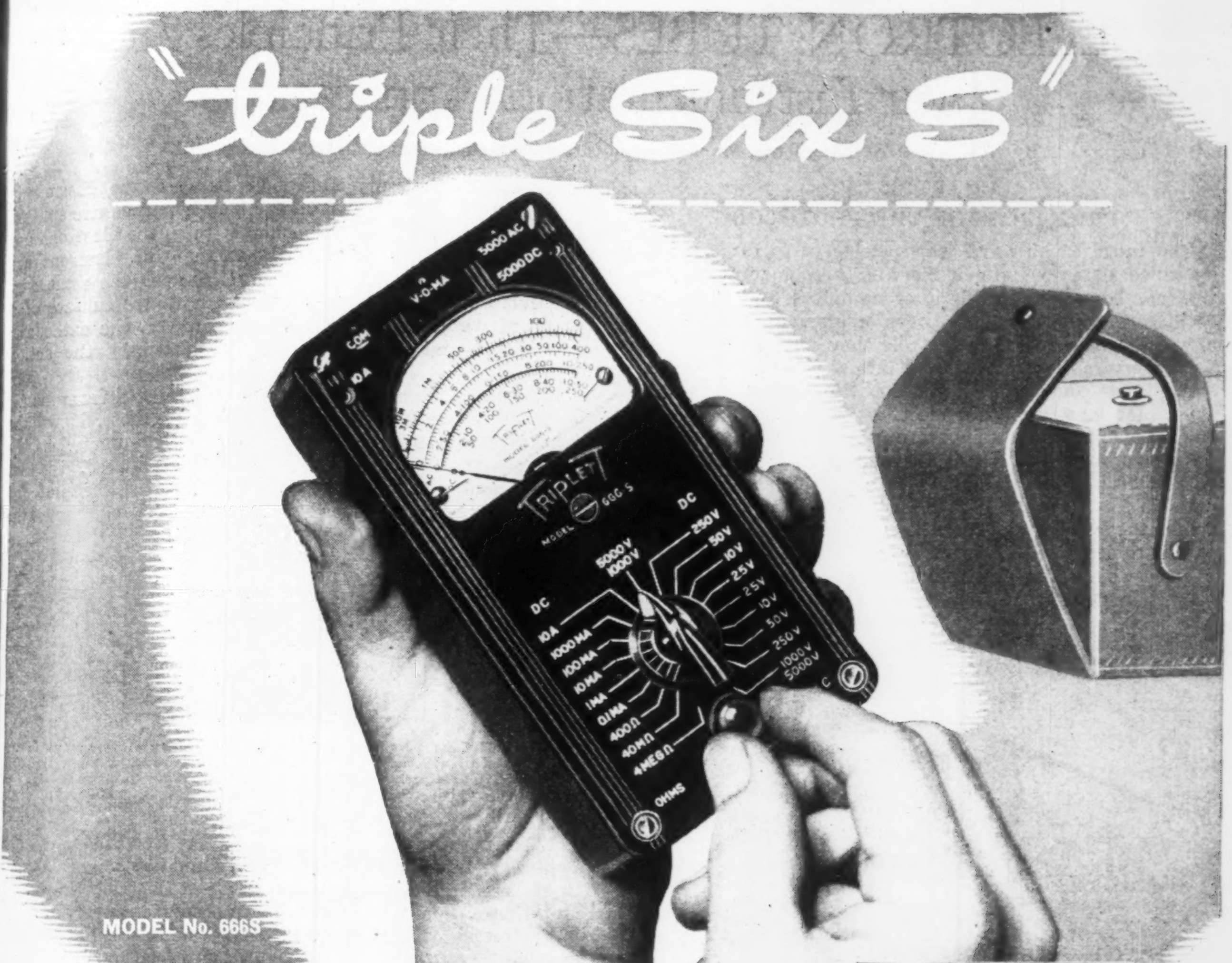
A permanent record should be maintained of all such complicated setups since the problems involved, or similar problems, will recur. More advanced gage checkers will usually maintain their own notebooks, but a permanent record may also be maintained by taking photographs of the setups. This will usually be found less expensive.

The most important function is, of course, to determine whether the gage is satisfactory for the inspection of parts. The person or persons responsible for these decisions must coordinate all information collected and interpret this in terms of acceptability or rejection of the gage. Such a person must be a qualified gage checker.

It is perfectly possible under these conditions for as few as two such qualified gage checkers to direct the surveillance of a million-dollar or a million-and-a-half-dollar gage program.

It may seem from the foregoing that the original statement, "the ideal in a gage laboratory organization requires that all personnel who inspect gages be qualified gage checkers" is inconsistent in that less skilled personnel may be used for the gage inspection jobs. Economically, there is little difference in cost whether less experienced or "qualified gage checkers" are used. Not only can a qualified gage checker turn out considerably more dollar value of gages, but he is also more versatile in the jobs which he may do. An experienced gage checker can safely take short cuts that less experienced personnel cannot attempt.

(Continued on page 282)


"triple Six S"
MODEL No. 666S
TRIPLETT
MODEL 666-S
V-O-MA
5000 AC
5000 DC
COM
10A
DC
5000V
1000V
250V
50V
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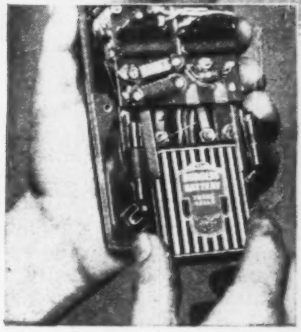
4MEGΩ
OHMS



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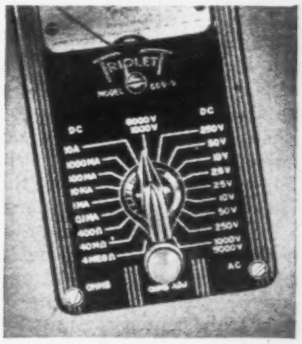

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ELECTRON TUBES—Their Principles and Their Instrumentation Applications

By ANDREW W. KRAMER, Managing Editor, Power Plant Engineering, Chicago, Ill.

CHAPTER XV

PRINCIPLES OF THE PHOTOTUBE

The tubes which have been considered so far can all be classified as serving one or more of three general purposes: they can be used as rectifiers, as amplifiers (or relays) or as oscillators, that is, as generators of alternating currents of any frequency. In the latter role they serve fundamentally as converters of direct current into alternating current.

All tubes considered, furthermore, are of the thermionic type, that is, a supply of electrons is produced by heating the cathode to a high temperature (above red heat). As will be shown later, there are other types of tubes also useful as rectifiers and as relays which do not depend upon a hot cathode for a supply of free electrons; these are known as cold-cathode tubes and form a separate classification. Before these are described, however, we shall consider another type of tube which is useful in industrial applications and which usually operates in conjunction with the types of tubes already considered. This is the photoelectric tube or the phototube as it is generally called.

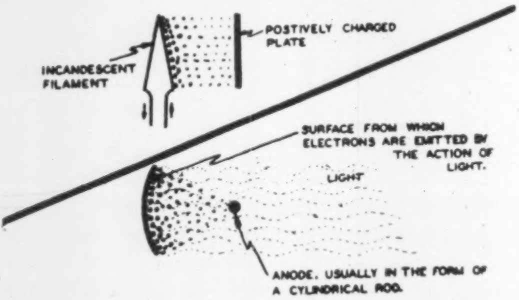
POSTIVELY CHARGED PLATE
INCANDESCENT FILAMENT
SURFACE FROM WHICH ELECTRONS ARE EMITTED BY THE ACTION OF LIGHT.
LIGHT
ANODE. USUALLY IN THE FORM OF A CYLINDRICAL ROD.

Fig. 101. Diagrams showing the difference between the thermionic diode and the phototube. The thermionic tube is shown above; here the electrons are "evaporated" out of the cathode by heat. In the phototube, shown below, the electrons are emitted from the cathode surface by the action of light.

The phototube, as its name implies, depends for its operation on the action of light or radiant energy. In the public mind, it is one of the wonders of the present age and popularly it has become known as the "electric eye," but this term is inaccurate because the phototube is simply a device which controls an electric current by the action of light. It is marvelously sensitive, however, and can be used as readily to measure the intensity and the quality of light from a distant star as it can measure the density of smoke in a Diesel-engine exhaust or in a steam power plant stack. In many applications it is used merely as a relay—to open or close an electric circuit by the incidence or interruption of a beam of light; in others it is used to modulate an electric current in exact accordance with minute variations in light intensity. In still other instruments, it is used to analyze colors. Its speed of action is almost inconceivable and it can follow variations in light intensity of millions of cycles per second without the slightest difficulty. It is the device that makes television possible.

Notwithstanding its amazing capabilities, the operation of the phototube is no more difficult to understand than that of the simplest thermionic tube, the diode. The only difference is in the way the electrons are emitted from the cathode, but in that we encounter one of the strangest things in modern physics. For here we encounter a fundamental interaction between light and matter—a phenomenon which has occupied some of the keenest minds of science for over half a century and which has led to startling changes in our whole understanding of Nature. These matters need not concern us here, however, but we shall discuss them later. At present we will concern ourselves only with the simple principles of the phototube's operation.

As stated, the only difference between the thermionic diode and the phototube is in the way electrons are emitted from the cathode. In the thermionic tube, the electrons are emitted by heating the cathode so that the electrons are virtually "boiled" out of the metal in much the same way that molecules of water are boiled out of the surface of a vessel of water. In the phototube, however, the cathode is not heated and the electrons are emitted by the action of light.

It has been found that electrons are emitted from metals in other ways than by heating. One of these, it will be recalled, was discussed in the preceding chapter when the principle of secondary emission was considered. In that phenomenon, electrons are "knocked" out of the plate by the impact of high-speed electrons traveling from the cathode.

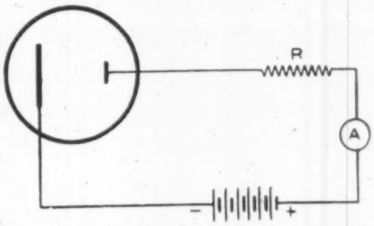

Fig. 102. The phototube circuit. Here a battery is connected in series with a resistor and a microammeter between cathode and anode. The current in the circuit develops an e.m.f. across the resistor which can be applied to the grid of an amplifier tube if desired.

Electrons can also be "knocked out" of substances by impinging x-rays or ultraviolet rays and by ordinary visible light rays. In the x-ray tube, high-speed electrons impinging on the target produce x-rays. This process, curiously enough, is reversible; when a beam of x-rays is directed at a metal surface, electrons are emitted from that surface. Since x-rays are a form of electromagnetic radiation, differing from light only in terms of frequency, it is conceivable that ordinary light might under favorable conditions have the same effect.

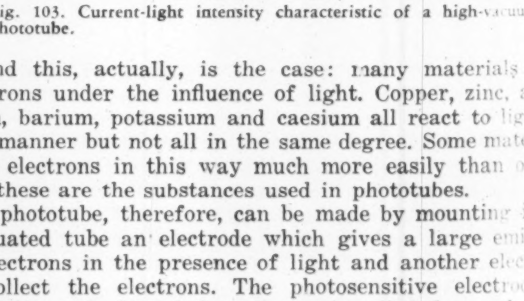

Fig. 103. Current-light intensity characteristic of a high-vacuum phototube.

And this, actually, is the case: many materials emit electrons under the influence of light. Copper, zinc, aluminum, barium, potassium and caesium all react to light in this manner but not all in the same degree. Some materials emit electrons in this way much more easily than others and these are the substances used in phototubes.

A phototube, therefore, can be made by mounting in an evacuated tube an electrode which gives a large emission of electrons in the presence of light and another electrode to collect the electrons. The photosensitive electrode is called the cathode and the collector is called the anode. The photosensitive material may be deposited on a curved metal plate as shown in Fig. 101 or, as is frequently done in present-day tubes, it may be deposited in the form of a thin layer on the inner wall of the glass tube. When made in the latter form, a portion of the glass surface is left clear so that light can reach the inside walls of the tube.

If a battery is connected to the electrodes of such a device, so that the photosensitive element is negative and the other element positive, practically no current will flow through the evacuated space if there is no light falling on the cathode. If light is allowed to fall on the cathode, however electrons will be emitted from its surface and, under the influence of the potential existing between the electrodes, will be drawn to the anode. Thus, a small current will flow in the circuit and this current is nearly proportional to the amount of light falling on the sensitive surface. Consequently, if a graph is made to show the relation between the electron current and the incident light, the resulting curve will be nearly a straight line as shown in Fig. 103.

The current delivered by a phototube of this type (or any other phototube for that matter) is very small, usually only a few microamperes. The curve shown in Fig. 103 gives the characteristic of the PJ-22 (G.E.) tube and, as will be seen, the maximum current is ten microamperes. As a consequence, such tubes must be used in conjunction with other amplifier tubes.

An example of such a combination is shown in Fig. 104 which is a diagram of a circuit used to measure light values by means of the phototube. In this circuit the voltage developed across the resistor R_1, due to the current in the phototube circuit, is delivered to the grid of the triode VT_1. This causes the current in the triode plate circuit to vary in direct proportion to the emission in the phototube, which of course depends upon the amount of light falling on the tube. The current in the triode plate circuit is read on the milliameter in that circuit.

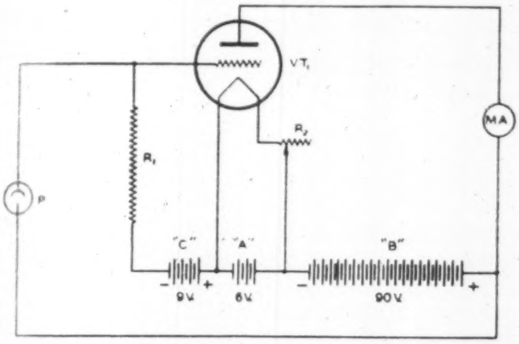

Fig. 104. Circuit diagram for measurement of variable light values with a phototube. Resistor R_1 may have a value of 2 to 10 megohms.

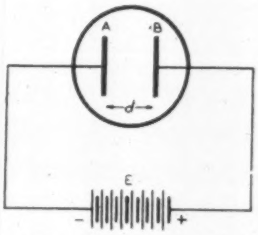

Fig. 105. Circuit and tube to illustrate the effect of "mean-free-path" in gases.

Ordinarily, in this type of phototube, a potential of 15 to 25 volts on the anode is suffifficient to attract the eelctrons emitted; increasing this voltage above this value causes little or no increase in current. This is due to the fact that the number of electrons emitted is always so small that a relatively low potential suffices to attract all of them to the anode.

The current through the tube can, however, be increased by introducing a small amount of low-pressure inert gas into the tube. Such a tube is called a gas-filled tube, to differentiate it from the "vacuum" tube we have been considring. Thus, as in the case of thermionic tubes, there are two general classes of phototubes: high-vacuum or simply vacuum tubes and gas-filled tubes. And, as in the case of thermionic tubes, the introduction of gas into the tube brings about an increase in current through ionization of the gas molecules. This increases the original current by as much as ten times. The amount of ionization increases rapidly as the anode voltage is increased until a point is reached at which the discharge breaks into a glow discharge. This glow discharge, if permitted, rapidly destroys the tube, so in practice it always is necessary to limit the anode voltage to a value below that at which this glow discharge occurs and usually a series resistance is incorporated for additional protection.

In the manufacture of these tubes they are filled with an inert gas at a pressure of about 0.1 mm. of mercury after they have been thoroughly evacuated and the cathode has been properly sensitized. With argon (commonly used for this purpose) this pressure gives a mean free path for the electrons of about 0.25 cm. The ionizing potential of argon is 15 volts, hence the potential gradient in the tube must be such that in moving 0.25 cm. the electron falls through a potential difference of at least 15 volts.

Although the process of ionization in gases was described briefly in Chapter VI, the action may require somewhat further explanation here. In order that an electron may hit a gas atom with sufficient force to remove an electron from that atom, it must be traveling at a certain minimum velocity. For some gases, depending upon how loosely or firmly the orbital electrons are held, this velocity corresponds to that which an electron acquires in falling through a potential of 15 volts.

To illustrate this, consider a glass bulb, as shown in Fig. 105, with two plates separated by a distance *d* and containing a small amount of argon gas. Assume that an electron starts from plate *A* under the action of potential *E*. Unless *E* exceeds the ionizing potential of the gas, there is no possibility at all of the electron acquiring sufficient speed to produce ionization even if it fell unimpeded from one plate to another. It is obvious, therefore, that the voltage *E* must be above the ionizing potential of the gas in the tube—in the case of argon, at least 15 volts.

PREVIOUS INSTALMENTS OF KRAMER'S BOOK

Chapter I Introduction, May '43; II Movement of Electrons in Conductors; III The Two-electrode Tube. Its Use as an Amplifier, June '43; IV The Triode as an Amplifier, July '43; V Amplifier Applications of the Triode, Aug. '43; VI Ionization, Oct. '43; VII The Thyratron: How it Works, VIII The Control Function of the Grid in Thyratrons, Nov. '43; IX Methods of Control in Using Thyratrons, Dec. '43; X Development of the Electron-tube Oscillator, XI Types of Oscillating Circuits, XII Neutralizing Electron-tube Amplifiers, March '44; XIII The Principles and Characteristics of the Tetrode, XIV The Pentode. The Principle of the Suppressor Grid, April '44.

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It can be shown, however, that if the tube is filled with gas at atmospheric pressure and with the electrodes only a centimeter or so apart, a potential difference hundreds of times as great as the ionizing potential of the gas can be impressed across the electrodes without producing appreciable ionization in the gas. This is due to the fact that the electron on its way collides with one of the numerous gas atoms in its path and so loses practically all the velocity it has gained. Then it will have to start all over again and before it acquires sufficient velocity to produce ionization it may collide with another atom and again lose all its velocity.

The "mean free path" of an electron, therefore, depends upon the average distance between the atoms of gas, and this, it is well-known, depends on the gas pressure. At atmospheric pressure the atoms are about one millionth of a centimeter apart, so it might seem that the electrons could scarcely move at all before colliding with a gas atom. This, however, is not true because the gas molecules are so small that even at this distance there is relatively ample space between them.

As the gas pressure is reduced, the mean free path of the electron is increased. With argon, as already stated, the mean free path at 0.1 mm. pressure is about 0.25 cm., and since the ionizing voltage of argon is 15 v. an electron will have to fall through at least 15-v. potential difference in a distance of 0.25 cm. to effect ionization.

Thus, the presence of gas obviously alters a phototube's characteristics, causing it to depart from the linear relation shown in Fig. 103.

A typical voltage-current curve for a gas-filled tube is shown in Fig. 106. The current, it will be noted, rises rapidly to the saturation value of the tube as a vacuum tube.* This saturation value of current holds, as the anode voltage is increased until ionization sets in, and here the ionized gas adds its current-carrying capacity so that the anode current increases to several times the true saturation current of the tube. As already mentioned, if too intense an ionization is employed, the tube becomes unstable and it may set up a glow discharge which persists independently of the incident illumination. The excessive bombardment of the cathode surface under these conditions results in its rapid and permanent deterioration. Usually an amount of ionization which gives an anode current from five to ten times the value of the photoemission is as much as can be safely used.

Although the glow discharge must be avoided in the operation of the ordinary gas-filled phototube, a tube of special design has been developed which utilizes this glow discharge effectively. This is the photoglow tube developed by D. D. Knowles. It is similar to the ordinary gas-filled phototube, but the gas pressure is considerably higher. They are operated with sufficient voltage between the electrodes so that the electron flow due to the photoelectric effect will ionize the gas and initiate a glow discharge. Since this glow is essentially an arc, with a constant arc voltage, the current through the photoglow tube bears no relation to the degree of illumination: it is limited only by the impedance in series with the tube and usually is sufficient to operate a magnetic relay without use of amplifiers. The characteristics of a typical photoglow tube are shown in Fig. 107. As will be noted, this tube has the property of locking in when energized from an a-c. source so that if the illumination is increased to a point above the start curve and then decreased, but not below the stop curve, the current will continue. On alternating current, of course, the current stops at the end of every half-cycle, but unless the illumination is reduced to a point below the stop curve, it will be re-established at each alternate half-cycle. This characteristic is useful in maintaining the current after it is started by a transient increase in the illumination.

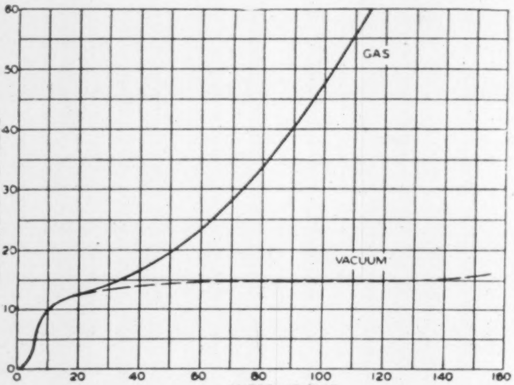

Fig. 106. Current-voltage curve of a gas-filled phototube. The lower portion of the curve corresponds to that of a high-vacuum tube. It is essentially linear until the saturation value is reached. Then as the anode voltage is increased ionization sets in and the current again rises rapidly. The curve for a high-vacuum tube under the corresponding condition of voltage is shown dotted.

Such tubes will carry as much as 5 milliamperes and they are designed for use where only occasional breakdown is encountered. Their field of application at present is quite limited.

To recapitulate: there are two general types of phototubes: (1) the high-vacuum type which has a decidedly linear characteristic but a low current capacity; (2) the gas-filled type which has a much higher current capacity but in which the voltage-current curve departs from a linear relation. The photoglow tube, of course, is a special form of gas-filled tube.

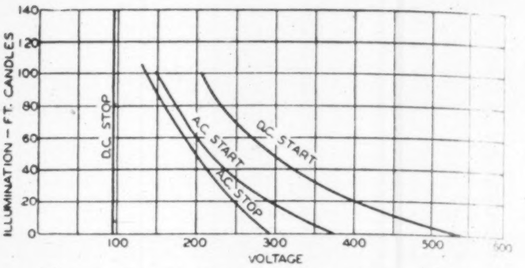

Fig. 107. The characteristics of the photoglow tube.

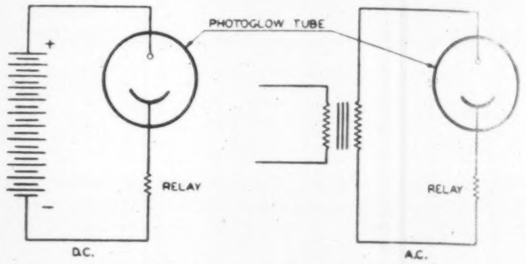

Fig. 108. Circuits showing the use of the photoglow tube with direct and alternating current.

The high-vacuum type of phototube is amazingly sensitive in its response and is capable of measuring the most minute and rapid variations in light intensity. There are other photoelectric devices available, which behave similarly, but none of these has the rapidity of action of the vacuum phototube. It is for that reason that the phototube finds application in television systems where speed of response is paramount.

Phototube circuits always have a battery or other source of potential in the circuit. In general there will be a small current to the anode even if no accelerating potential is applied to the anode, provided the frequency of the incident light is high enough, but this current is so small as to be negligible. The higher the voltage of the battery, the greater will be the photoelectric current up to the point where the voltage on the anode is high enough to attract all of the electrons emerging from the cathode surface. This is called the saturation current of the tube and corresponds exactly to the saturation current in the diode.

CHAPTER XVI

ELECTROMAGNETIC RADIATION AND THE PHOTOELECTRIC EFFECT

The photoelectric effect is the name given to the power of light, x-rays and similar radiations to cause certain substances to emit electrons, and, as such, it is the principle which has made possible the phototube. The phenomenon is important and interesting from several points of view, chief of which is that it represents one of the three or four funfundamental interactions between radiation and matter. By this we mean that it concerns the way in which energy in the form of light and x-rays is handed over to matter and vice-versa. It is a strange phenomenon; indeed, in the explanation of the photoelectric effect we come as close to one of the fundamental secrets of nature as we do in any study man has engaged in. Indeed, it was the inconsistency of the laws of photoelectricity with the wave theory of the nature of light that led Einstein to postulate that light was corpuscular in nature and that each light corpuscle or "quantum" coudl give up its energy to an electron of the photoelectric surface.

As was shown in the preceding chapter, the phototube is easily explained; it is simply a device for controlling an electric current by means of light. Now, we will concern ourselves with a more detailed consideration of the photoelectric effect itself. Those who are interested only in the simple action and application of the tube but not in the theories underlying its action may skip this, but to those really interested in knowing what it is all about, this chapter should provide plenty of food for thought.

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*By saturation value, of course, is meant the point at which the anode voltage is sufficient to attract all of the emitted electrons to the anode.

The laws governing photoelectric phenomena are easier to express than to understand. Their study has raised many points of great interest regarding our views as to the real nature of radiation since they attribute to light a behavior apparently irreconcilable with the simple continuous wave theory used to explain light phenomena. Also, they maintain their validity over an enormous range of wave-lengths, a fact difficult to explain. Ordinary visible light, for example, has a wave-length a million times greater than that of short x-rays, yet the relation governing the speed of the ejected electrons is the same in both cases.

No attempt will be made to present an exhaustive discussion of the nature of electromagnetic radiation, but in order to discuss the photoelectric effect, certain facts regarding radiation should be understood. We should know to a certain extent what is meant when we speak of electromagnetic radiation. All of us know in our minds what is meant when we speak of light, or heat, or even x-rays, though it might be difficult to explain these terms. When we speak of radiation, however, we may not be so sure as to what is meant—it is a more technical term; yet light, heat and x-rays are all examples of radiation.

All of you have sat in front of a stove on a cold winter day and watched it turn first a dull red and then a cherry red. As it became red hot you backed away from the intense radiant heat that was thrown out and sought a cooler spot. Did you ever wonder about the invisible radiation that was emitted before the stove became red hot? You must have noticed that even before the stove turned red hot, you could feel the heat; you could not see anything, however. What really happened? If that which warmed you when the stove was black was heat, what was it when it turned red? Are there different kinds of heat? Is black heat different from red heat?

To most of us who have studied even the simple elements of physics these questions answer themselves. We know only too well that the heat from the black stove is not fundamentally different from that from the red-hot stove except that at the latter stage it is more intense and that it affects our sense of seeing as well as of feeling. At the red-hot stage, we learned at school that the radiation is of shorter wave-length or higher frequency. Radiation, we were told, was largely a matter of frequency or wave-length. We can see radiation of only certain wave-lengths; specifically, only those wave-lengths between 7700 and 3800 Angstrom units.* In other words, the eye is sensitive only to the wave-lengths in this range. As we shall see, all radiations can be expressed in terms of their wave-length. Those lying in the range just below 3800 Angstrom units are called the ultra-violet radiations, because they lie just beyond the violet end of the spectrum. We can neither see nor feel the ultra-violet radiation but, as will be shown, they have pronounced photochemical and photoelectric as well as biological effects.

Above 7700 Angstrom units are the infrared, so named because they lie in that portion of the spectrum just beyond the red in the visible range. Our eyes cannot see the infrared but we can feel them and in everyday experience we recognize them as heat. These are the radiations which the stove sends out before it becomes red hot.

Between these infrared radiations and the ultraviolet, are the radiations which the eye can "see." It is true that when the stove is red hot we both feel and see radiation, but this is because there is a mixture of light and infrared waves. If the latter are filtered out, we no longer feel the radiation coming from the stove but we still see it.

The point we are trying to make clear here is that the mere changing of the wave-length of radiation causes it to exhibit widely different effects. In Fig. 109 is shown a scale, known as the electromagnetic spectrum. It is nothing more than a scale representing the lengths of various kinds of electromagnetic radiation of which we have knowledge. It looks quite simple and is quite simple, yet in many ways it is a wonderful thing. Its length, or rather its growth, is very much a measure of the growth of man's scientific knowledge. At one time the only portion of it of which man had any knowledge was the small central portion labeled visible light and a portion of the adjacent region called the infrared. For many centuries, indeed for the greater part of man's existence on earth, these were the only portions of this scale of which man had knowledge.

Later, and remember, all this occurred within the last hundred years, the existence of electric or "radio" waves was predicted and discovered. Next came knowledge of the x-ray and the gamma rays from radium and as each of these was studied they were found to fit into a definite place in the electromagnetic spectrum; they all appeared to be members of the same family. At first there were many gaps but these have gradually been filled so that today we have practically a continuous scale extending from the infinitely short rays of radium, less than a hundred millionth of a centimeter in length to the very long radio waves of the transoceanic wireless stations, 20,000 or more meters in length. This entire vast range of lengths is represented by the scale in Fig. 109.

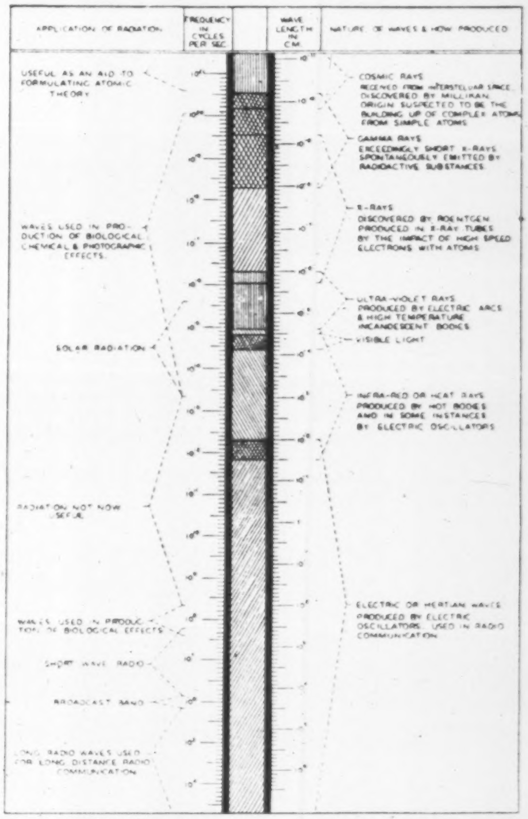
APPLICATION OF RADIATION
FREQUENCY IN CYCLES PER SEC
WAVE LENGTH IN CM
NATURE OF WAVES & HOW PRODUCED
USEFUL AS AN AID TO FORMULATING ATOMIC THEORY
WAVES USED IN PRODUCTION OF BIOLOGICAL CHEMICAL & PHOTOGRAPHIC EFFECTS
SOLAR RADIATION
RADIATION NOT NOW USEFUL
WAVES USED IN PRODUCTION OF BIOLOGICAL EFFECTS
SHORT WAVE RADIO
BROADCAST BAND
LONG RADIO WAVES USED FOR LONG DISTANCE RADIO COMMUNICATION
COSMIC RAYS
RECEIVED FROM INTERSTELLAR SPACE DISCOVERED BY MILLIKAN ORIGIN SUSPECTED TO BE THE BUILDING UP OF COMPLEX ATOMS FROM SIMPLE ATOMS
GAMMA RAYS
EXCEEDINGLY SHORT X-RAYS SPONTANEOUSLY EMITTED BY RADIOACTIVE SUBSTANCES
X-RAYS
DISCOVERED BY ROENTGEN PRODUCED IN X-RAY TUBES BY THE IMPACT OF HIGH SPEED ELECTRONS WITH ATOMS
ULTRA-VIOLET RAYS
PRODUCED BY ELECTRIC ARCS & HIGH TEMPERATURE INCANDESCENT BODIES
VISIBLE LIGHT
INFRA-RED OR HEAT RAYS
PRODUCED BY HOT BODIES AND IN SOME INSTANCES BY ELECTRIC OSCILLATORS
ELECTRIC OR HERTIAN WAVES
PRODUCED BY ELECTRIC OSCILLATORS. USED IN RADIO COMMUNICATION

Fig. 109. The electromagnetic spectrum.

All of these radiations, light, x-rays, radio waves, were regarded as being vibrations or waves in a purely imaginary medium called the ether. Though the most elaborate experiments were devised, and set up, no proof of the existence of an ether was ever shown but a wave had to be a wave in something and so the ether was invented. It served as a convenient explanation for the action of light, radio and x-rays. Just as a disturbance in water produces a wave which travels outward from the point of disturbance, so it was thought that a disturbance in the ether produced light waves or x-rays or radio waves. All of these waves, it was shown mathematically and experimentally, traveled at the same speed, at the rate of 3×10^{10} cm. per second, the velocity of light. The only difference between the waves of light and the waves of the x-ray or any of the other radiations, it was demonstrated, was in their length. And since the speed was constant, it was apparent that there was an inverse relationship between the wave-length and the frequency of vibration; as the wave-length becomes shorter, the frequency becomes greater and vice-versa. In other words, the product of the frequency multiplied by the wave-length always equaled the velocity of light, 3×10^{10} cm./sec.

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*The Angstrom unit is the conventional unit for the measurement of wave-length when dealing with x-rays, light, etc. It is the one hundred millionth part of a centimeter.

This wave theory served well; it explained the properties of light in a way that no other theory had been able to do before. On the basis of this theory light was a form of energy stored in the ether which traveled outward from its source, spherically, in all directions. The energy at any point in space varied as the distance from the source; the energy of the wave was less the further it traveled from its source, just as the circular waves which spread out from a stone dropped into a pond grow weaker as they spread out from the center. All this was quite simple and easy to understand—if you could imagine the ether.

Now, we can return to our red-hot stove. As the stove turns from black to red, that is, as the temperature rises, the frequency of the radiation increases and, conversely, the wave-length decreases. Now, we know that as the temperature rises we get warmer and back away from the stove; we can stand or sit at a considerably greater distance and yet feel just as much heat as we did up closer when the stove was still black. There seems to be more energy in the high-frequency heat waves than in the lower-frequency waves.

This, it can be demonstrated, is an actual fact. The total radiation coming from a stove or any such black body increases very much as the temperature rises, in fact it increases as the fourth power of the absolute temperature.

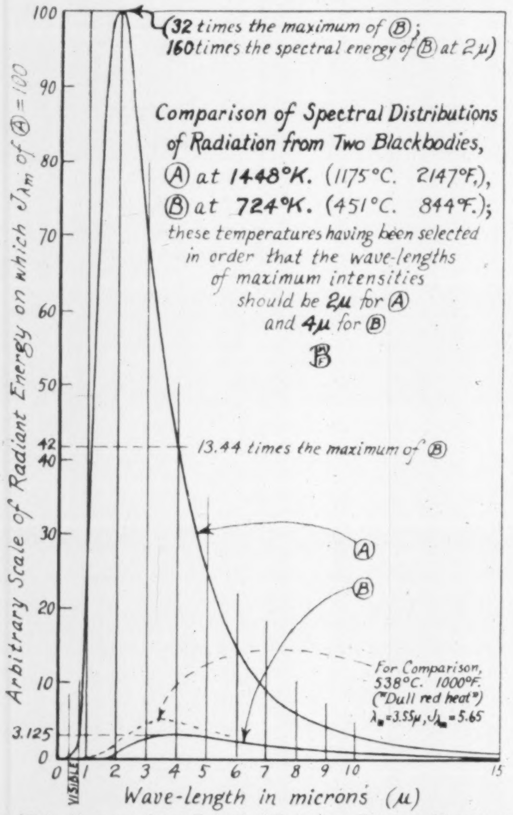

Fig. 110. This diagram, from Behar's "Relations Between Temperature and Radiant Energy," shows the distribution of radiation from "blackbodies"—bodies which radiate or absorb perfectly, hence which are the brightest of all bodies when very hot and the blackest when cold. Black-oxidized iron is almost a perfect blackbody, so that Curve B represents the wave-length distribution from a stove which is "black-hot"—about 160°F. below dull-red. The wave-length of its most intense radiation is 4 microns (or 40,000 Angstrom units, or 0.0004 cm.) which is in the infrared. (See Fig. 109.)

Curve A represents the radiation from a yellow-hot stove. Its peak of intensity is still in the infrared, at 2 microns. Its red radiation is about twice as intense as its yellow radiation, but the human eye is ten times more sensitive to yellow than to red, so that the light seems yellow.

The absolute temperature of A is twice that of B. Therefore, by the fourth-power law, the area under Curve A, representing watts per square inch of stove surface, is 16 times (2 × 2 × 2 × 2) that under Curve B.

At 1000°F. a piece of iron begins to radiate visible red light, as shown by the dotted curve. An interesting distribution curve is that of the sun: its peak is very close to that of the eye—about 0.55 micron. One reason why Behar did not draw it is that its peak would be 500 inches high if drawn to the same scale of intensities!

By breaking up the radiation from the stove into its separate wave-lengths by means of suitable prisms and lenses and measuring the intensity of the radiation in these various wave-lengths, it can be shown that the hotter the stove, the shorter the wave-length and a set of curves can be drawn to illustrate this.*

To plot such graphs and to demonstrate that this was true was one thing, but to account for it on the basis of purely theoretical considerations was quite another, and a great deal of effort was spent in trying to find an equation which fitted these graphs.

It was not until around 1900 that any success was had but then Max Planck finally succeeded. In doing so he made some radical departures from the accepted physical principles of the time. Until that time it had been thought that an atom radiated energy continuously. (You probably are wondering what all this has to do with phototubes but, don't worry, we'll come to that.) Planck assumed that the atoms radiate energy discontinuously—in bundles, so to speak. An atom could release a whole bundle of energy but not part of a bundle. Furthermore, he gave the law by which energy is radiated under this assumption. It was

$$\text{energy of quantum} = h\nu$$

where ν is the frequency of the radiation, and h is a universal constant known as Planck's Constant and is equal to 6.55×10^{-27} erg.sec. This law and this constant have since become quite famous and it has appeared in all sorts of rather unexpected places. It is fundamentally connected with the mechanics of the atom.

In the meantime, the study of the photoelectric effect had started in 1887 when Hertz found that light falling on a spark gap enabled a discharge to pass more easily than when the gap was not illuminated. A year later Hallwachs made the important observation that ultraviolet light falling on a negatively charged zinc plate cause a rapid loss of charge. The next year (1889) Elster and Geitel showed that no loss of electricity occurred when the plate on which ultraviolet light falls was initially positively charged. So the study went on and it was not long before the cause of the behavior was discovered. In 1899 J. J. Thomson and P. Lenard showed independently that the action of the light was such as to cause the emission of negatively charged particles—electrons. In some strange way, when light fell upon the surface of a solid body, electrons in that body "flew out."

Shortly afterwards, in 1902, Lenard opened up a new method of attack when he directed attention to the maximum energy of the ejected electrons. He was able to show that the maximum velocity of the ejected electrons was independent of the intensity of the light but depended upon the source from which the light came. Ladenburg and other scientists then showed conclusively that the energy of the fastest electron ejected from a given surface (such as zinc, lithium, thorium, etc.) depends entirely upon the wave-length or the frequency of the radiation.

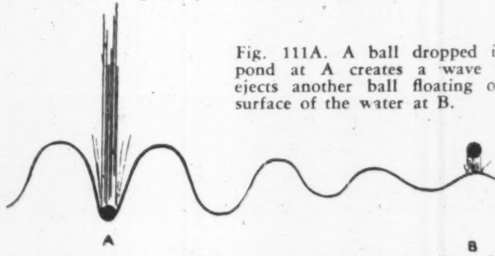

Fig. 111A. A ball dropped into a pond at A creates a wave which ejects another ball floating on the surface of the water at B.

To one familiar with the wave theory of light, this was a strange discovery. No wave theory of light could explain it. On the basis of a wave theory, it is conceivable that if a ball is dropped into a pond as shown in Fig. 111A another ball floating on the surface of the water some distance away might be lifted upward by the waves reaching it. One would not expect this second ball to be lifted very high,

(Continued on page 288)

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*See, for example, "Relations between Temperature and Radiant Energy" by M. F. Behar, *Instruments*, Nov. 1940, pages 341-345. This is a non-mathematical discussion.

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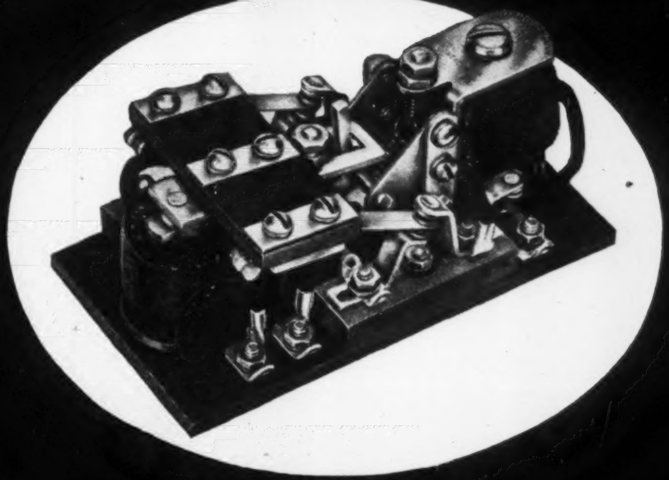

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Aviation Instruments
Navigation Automatic-piloting Power plant Automatic-landing Aerological
Communication Flight-testing Production Instrument-testing

Vol. III, No. 5 M. F. Behar, Editor May 1944

How "The Guys on the Ground" Won "The Battle Against Sand"

By Captain ALFRED FRIENDLY, ASC, AAF.

IN the February *Instruments* the feature article was a profusely-illustrated description of the Air Service Command's instrument repair and calibration semi-trailer; the front-cover photograph was a general view inside this mobile shop and laboratory.

Although large numbers of these special trailers have been shipped overseas, it must not be inferred that all hardships are ended for all AAF instrument repairmen on all war fronts. Warfare isn't like that: it frequently makes impossible the use of equipment especially made for convenient servicing of aircraft instruments. Even if instrument semi-trailers had been available in large numbers before Pearl Harbor and were available in enormous numbers today, they could not be used everywhere. Nor could they be used at all times—certainly not during the time which may be described as "the early stages."

Most of the First and Second Echelon Maintenance men—and many in Third and Fourth Echelon groups relatively far behind the front lines—work under adverse conditions today; and will always work under difficult conditions until the war is won.

A glorious chapter of resourcefulness and inventiveness as well as devotion to duty is being written by maintenance men—real experts today, although less than five percent of them had received special training before Pearl Harbor.

Typical of their work is the story of the group at a Middle East AAF depot located in ankle-deep powdery sand—sand never packed hard by the waves of the sea—the burning sand of a place where, in daytime during the summer, metal parts shaded from the direct rays of the sun are almost too hot to touch. (See Fig. 1.)

This supply and repair depot is, to be sure, behind the front lines and behind the scenes. And, as far as recognition of its work by the folks back home, or even knowledge of the existence of bases like this, it has also been behind the eight ball.

It is an integral part of the Air Service Command, itself a behind-the-scenes organization charged with worldwide overall aircraft supply and maintenance functions.

The repairmen's record is an astounding one. Their work in reclaiming precision instruments (see Fig. 2) has been phenomenal. This work has been done with a minimum of equipment and tools. To make up for deficiencies, the GI mechanics simply invented and manufactured their own.

Staff Sergeant James E. Sims, of Compton, Cal.; Technical Sergeant E. H. Johnson, of Elk Point, S. D.; Private First Class James Cavalier, of Jeannette, Pa., with the assistance of civilian technicians from the Douglas Aircraft Corporation, such as Ted Lamparter, of Lancaster, Pa., set up their own instrument shop. After they built it and installed equipment, much of it home-made, they tested and repaired 1200 of the complex instruments that go into a modern combat airplane, sending them out ready for

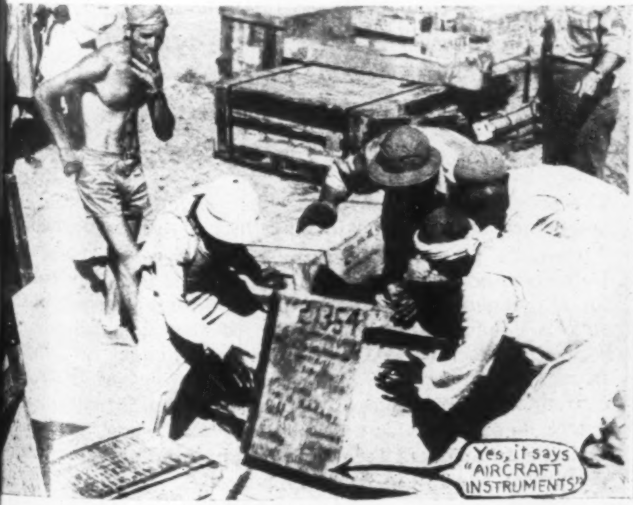

Yes, it says "AIRCRAFT INSTRUMENTS"

Fig. 1

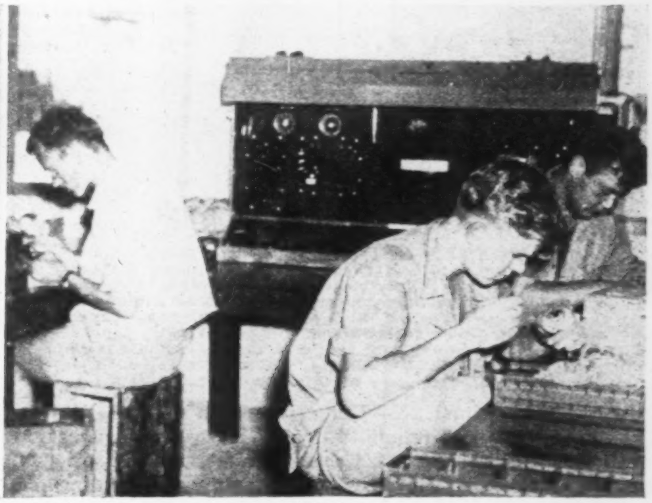


Fig. 2

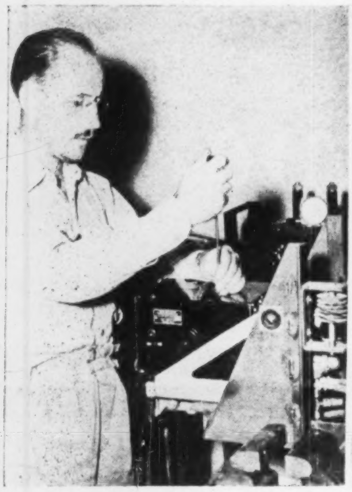


Fig. 3

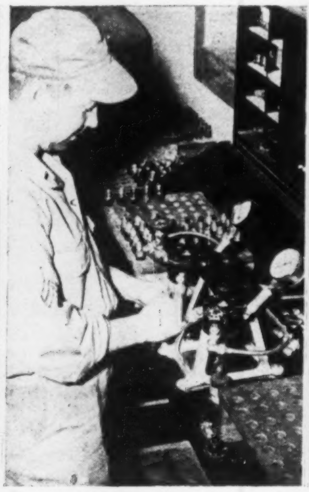


Fig. 4

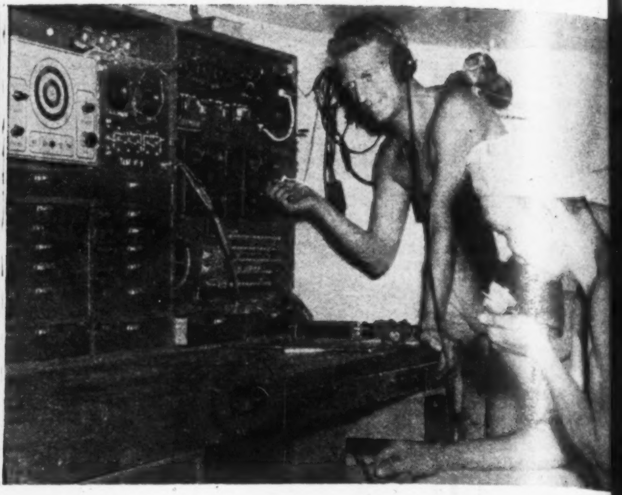


Fig. 5

immediate installation wherever needed. This number, 1200, is months old; today's total is of course much higher.

To test automatic pilots, as tricky and as delicate an instrument as there is in the books, a scientifically-correct device was home-made—or rather desert-made, by J. C. McPhie, of Salt Lake City, Utah, a Douglas Aircraft Corporation employee attached to the Air Depot Group. (See Fig. 3.)

Sergeant Clarence M. Cash, who worked in the Allison Motors Plant in Indianapolis, Ind., until his wife, Hazel, replaced him when he went to war, has designed and made almost all the depot's extensive testing equipment for spark plugs, and has thereby supplied to Middle East aircraft some 66,000 of these vital items. (See Fig. 4.)

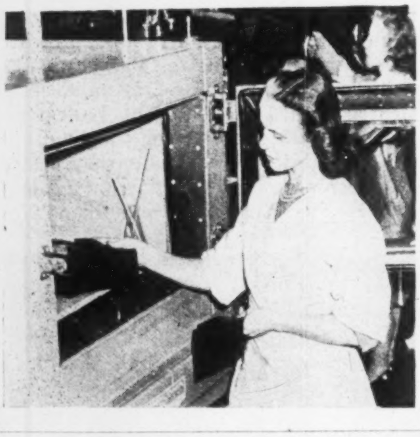
Because it would take from five to ten days to get instrument glass, the men made their own out of aircraft Plexiglass. They made instrument dials out of Bakelite and used Plexiglass to replace non-available slate insulators.

Signal Corps men (see Fig. 5) attached to the Air Service Command service center have been no less ingenious than the aircraft instrument repair men. In the radio shop, for example, they found that usual rubber shock cord simply would not hold up under pressure in desert conditions. They made a substitute out of a spring—they had to make the spring, too—and a porcelain insulator. The substitute is practically standard equipment by this time.

Such is the work of the guys on the ground. It's fairly satisfying, too. According to Master Sergeant Robert M. Price, Scranton, Pa., boss non-commissioned officer of the group's engineering office, "You get quite a kick out of it when you see them take off. You know that they wouldn't be flying if the gang hadn't cured them when they were sick."

By the time this article appears in print, the individuals mentioned by name have probably received the latest equipment. Perhaps *they* are working in air-conditioned mobile instrument shops. But their story is typical: it is being duplicated at this very moment in many Air Service Command bases throughout the world, with other difficulties than desert sand to overcome, but always in the face of unexpected difficulties.

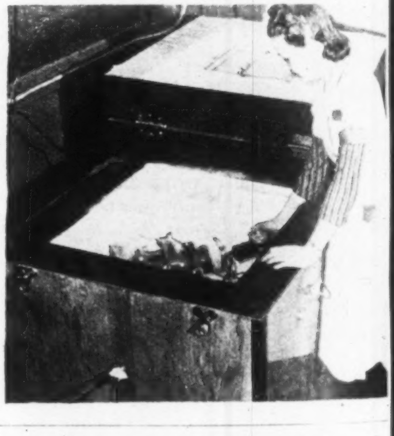
Cold Tests



IN contrast to the Air Force photos of instrument work in hot deserts, these two from the Eclipse-Pioneer Division of Bendix Aviation Corporation at Teterboro, N. J., show cold tests of materials and assemblies:

(left) Testing aircraft-instrument rubber and other materials at −60°F.;

(right) Performance test of an aircraft starter to determine correct lubricants: note the use of a hand tachometer.



UAL's Post-war Jobs

[*EDITOR'S NOTE—At present, readers of this department are all helping to win the war, but they are interested also in post-war opportunities for the skills they have acquired. The following news release is so enlightening that we print it in full. We do not thereby imply that all airlines, all aircraft instrument companies, etc., have exactly similar plans; nor that the UAL plan is the only perfect one; we believe, simply, that it deserves wide publicity among the readers of this department.—MFB.*]

CHICAGO, April 25.—Extensive plans not only for the re-employment and rehabilitation of its own personnel now on leave with the Armed Forces but for the absorption of large numbers of entirely new employees following demobilization, were disclosed today by United Air Lines. The program was described as indicative of the prominent role which the airlines will play in post-war employment.

United's plan has been in quiet operation since last December, according to R. F. Ahrens, the company's director of personnel. It calls for periodic contacts with in-the-service employees; rehabilitation of the physically handicapped; indoctrination on important changes within the industry and specific training consisting of refresher courses in various company activities; familiarization with new company policies and post-war plans, and specialized training to augment technical training and other education acquired while in the Army or Navy.

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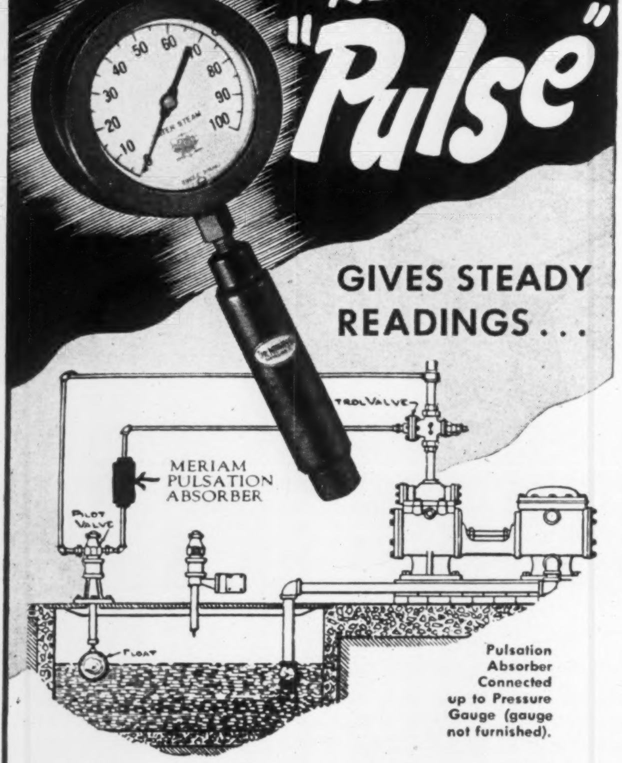

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MANOMETERS, METERS AND GAUGES FOR THE ACCURATE MEASUREMENT OF PRESSURES, VACUUMS AND FLOWS OF LIQUIDS AND GASES

pectancy of additional numbers annually for the duratio United felt that plans for their re-employment should b started now rather than at the conclusion of hostilitie Ahrens said.

Briefly, the rehabilitation program operates like this:

1. Questionnaires have been sent to every employee o military leave, requesting information concerning militar record, experience and education acquired while in servic Thus far, 75 percent of such questionnaires have been answered. Approximately 12 percent of the individuals hav indicated a desire to enter a different job classificatio when they return to the company; 75 percent have receive specialized training since going into service.

2. As soon as the serviceman is demobilized, he will report to any United personnel office, stating his futur plans and giving the approximate date on which he wi be able to report for re-employment.

3. He will be entered on the payroll at the same salar he received before going into service. His personnel recor will be reviewed; he will indicate his choice of job, wi undergo complete physical examinations, will fill out various company personnel records and, after discussions wit various department heads concerned with his case, will b assigned to his old or a new position. He then will tak the prescribed indoctrination and refresher training fo that job.

"United's personnel has increased from 4,300 in 194 to nearly 8,000 in 1944," said Ahrens. "This figure is expected to jump to more than 18,000 within four years afte the war. The estimated increase will enable us to re-emplo not only our own personnel but also ex-servicemen wh entered military life directly from schools, colleges or othe jobs. Already we have a file of some 800 such individual who have expressed a desire to join the company when th war is over. These will be contacted periodically along wit the company's employees in service to determine their additional military education.

"Our big objective is to see that the way is paved fo the smoothest possible absorption of our returning servic men and women on a basis that will give them due credi for all pertinent experience gained in the armed services also, to obtain from the demobilized ranks as many new personnel as seem likely to fit into our expanding picture All this is in line with our philosophy that business wil have definite responsibilities for the solution of socia problems in the post-war period."

Criticizes Q&A Type Quizzes

To the Editor of *Aviation Instruments:*

I have read the article in your March issue by Charles S. Bellin, AAF, describing his quiz. As I have disagreed with everyone else advocating this type of test I may as well go on record as disagreeing with Mr. Bellin.

In general, this type of test, known as the "objective test," is not intended to measure the knowledge of an individual but rather to measure the comparative knowledge of a group of individuals. It has no value in teaching; its false statements confuse the student.

In particular, Mr. Bellin's test contains nearly all the irrelevant questions ever propounded. For example: "True or false—the oil temperature gage should read approximately 100°C. before taking off." Of what possible value is such a question to a mechanic concerned only with repairing instruments?

Please do not consider this criticism a personal attack on Mr. Bellin, yourself or your splendid magazine, but rather as a plea for better tests for the poor mechanic who has to struggle through page after page of immaterial questions that only serve to confuse and bewilder him.

Why can't we take our cue from the highly efficient CAA officials? When I stood my instructor's examination, they gave me just five Essay type questions which took me approximately six hours and 18 pages to answer but which gave them a pretty fair idea of what I as an individual knew. I sincerely trust that the CAA is still using this type of test, and not the objective "guessing game" type.

Inasmuch as this is an Air Service Command School

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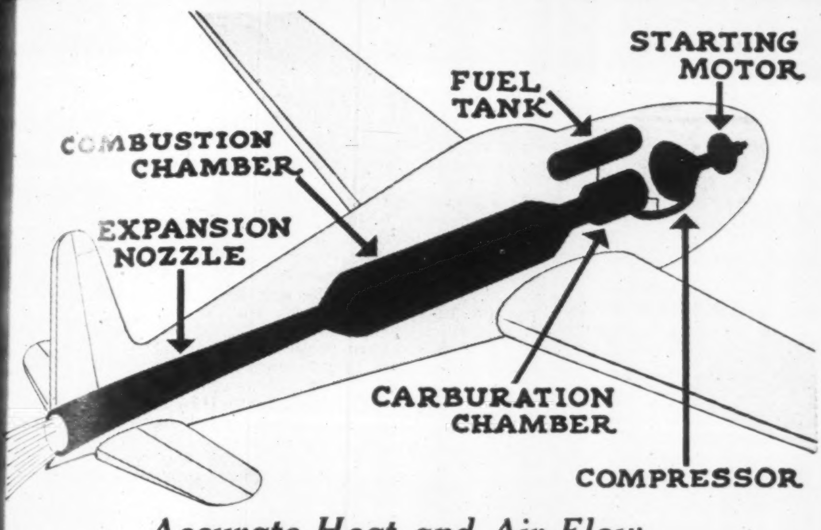

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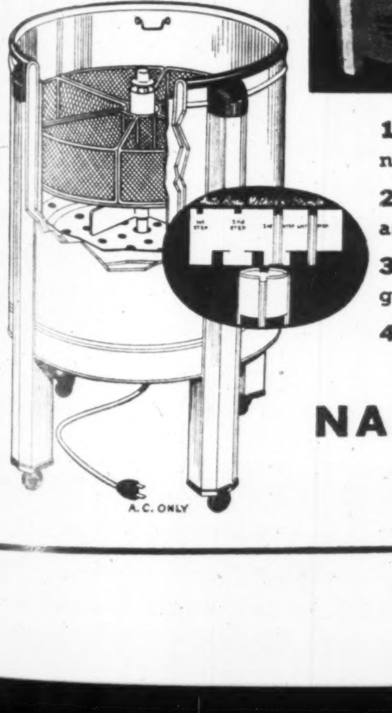

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WRITE FOR LITERATURE

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I am using objective type examinations in accordance wit our Instructional Units Policy; and the opinions I have expressed here are strictly my own. Any AAF instructor ca secure a copy of our testing material by writing to Curriculum Unit, MoASC, Maintenance Training, Brookle Field, Mobile, Ala.

R. T. HARRIS
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Pressure & Mech'l Instr'

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Mobile, Ala.

EDITOR'S REPLY. This type of test permits an instructor to grad or score each individual student at the end of every week o month of instruction which has been given *uniformly* to all students. This is not only a time-saving convenience (hence valuab when a nation must train an army rapidly) but it is sanctione by pedagogical authorities. However, although educators approv this TYPE of examination, they warn that the FORMULATION o questions and statements must be governed by general principle of psychology, etc., and by the specific requirements of the grou and situation. In short, it's a job for experts.

Instructor Harris may have become disgusted with this typ of test by reason of cheap radio and newspaper quizzes and othe horrible examples, but Instructor Bellin reported in our Marc issue that *his* test was used "with amazing results . . . man participants were seeking references on the subjects involved an studying them for the first time." (That's one reason why hi article was featured.)

The definition of "objective" given by Instructor Harris differs from that of educators, who use it to signify absence of "subjective" factors such as graders' personal opinions, favoritism, etc To me, "objective" connotes the antithesis of "emotional" o "prejudiced."

As for the CAA examiners (whom I, too, admire), they naturally wouldn't rely on time-saving "true-or-false" quizzes whe selecting INSTRUCTORS!

Quizzes proved useful to the hundreds of officers, enlisted men and civilians whom I taught, but that was a quarter-century ag and Instructor Harris may be right. The final judges today ar the official heads of the ASC instrument-repairman training program, who will order all necessary changes if Instructor Harris proves his case—to them, not to

MFB

Reader Spots Flaws in March Quiz

To the Editor of *Aviation Instruments:*

In Charles S. Bellin's article "A Time-tested Test On Instruments" (March 1944 issue) I find the following errors in the answers to the questions.

Question No. 15: The author probably has reference to the coiling of the capillary tubing of a vapor-pressure type thermometer, as a tachometer drive shaft is never coiled in good practice.

Question No. 25: The approximate speed of the gyroscope in the turn indicator (suction-operated which the author probably has reference to) is 9,000 r.p.m. The approximate speed of the gyroscope in the Directional and the Flight Indicator is 12,000 r.p.m.

Question No. 48: The damping cylinder in a (suction-operated) Turn and Bank Indicator is used to prevent overtravel of pointer on returning to the vertical (center) neutral position, after the aircraft has stopped turning—not to regulate the precession of the gyro assembly as the aircraft turns. The sensitivity spring balances (regulates) the gyroscopic reaction (precession) during a turn.

Question No. 50: Oil is added to the wick of the Turn and Bank Indicator approximately every 100 hours, not approximately every 400 hours.

PVT. JOSEPH WALACONIS
A.A.B. Pocatello, Idaho

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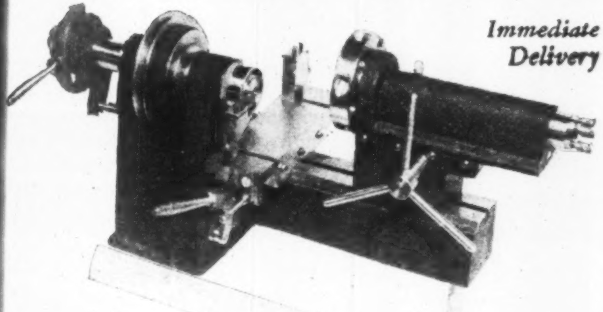

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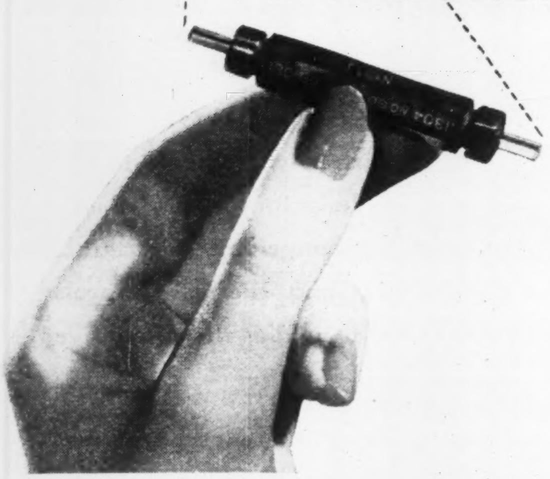

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ORDNANCE PRODUCTION GAGING

(Continued from page 266)

such as the use of a height gage for measuring accurately to 0.001″ when a tolerance of 0.001″ is given. Further, more experienced supervision is required for less skilled personnel.

TRAINING

The success of using less experienced personnel for gage inspection rests upon the training system used. Properly trained, women make very apt gage inspectors. They have a delicacy of touch which lends itself well to the use of precision equipment. A high-school education and willingness are about all that are required for the more routine jobs in a gage laboratory. A knowledge of mathematics and especially geometry and trigonometry are essential if the person is to assume setup jobs.

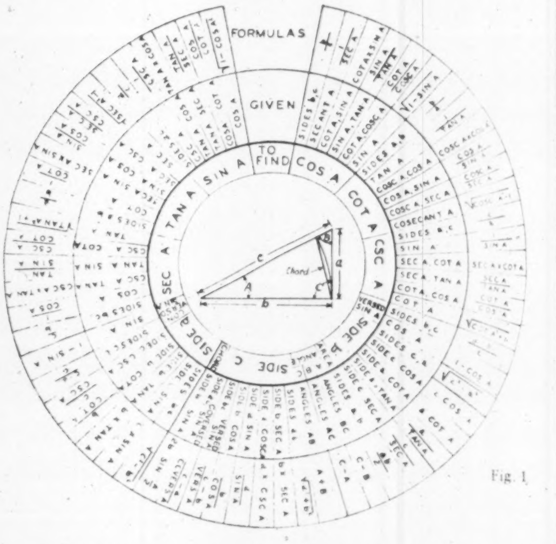

Fig. 1

Following are several outlines of basic courses which have been used successfully in the instruction of personnel to assume the more routine inspection duties. It is probably more satisfactory to "learn by doing" under competent supervision with the courses shown broken into small increments and presented intermittently over a period of several weeks. For the more apt personnel, instruction in trigonometry will probably pay dividends. This instruction should be centered purely around right-angled trigonometry since only a very small proportion of work in any laboratory will require mathematics of a higher degree. The chart, Fig. 1, has been found quite helpful in the solution of the more simple trigonometric problems.

OUTLINE OF INSTRUCTION FOR GAGE CHECKER

A. General
  I. History
    (a) Standards (development, ancient to modern)
    (b) Interchangeability (Eli Whitney)
  II. Interchangeability
    (a) Tolerance, allowance, wear
    (b) Systems (unilateral—bilateral)
    (c) Basic size
    (d) Component—define
  III. Drawings
    (a) Component and gage
    (b) Terms, symbols, kinds of line
    (c) Views
    (d) Visualization
    (e) Work out a drawing for an actual object
  IV. Gages (definition)
    (a) Advantages and disadvantages
    (b) How applied and why
    (c) Tolerance
      1. Varies according to size
      2. 10% rule
    (d) Wear
    (e) Kinds of gages and use
      Snap, Flush Pin, Plug and Ring, Profile, Receiving Spanner, Concentricity (inside and out), Taper (ring and plug), Thread (ring and plug) etc.

(Concluded on page 284)

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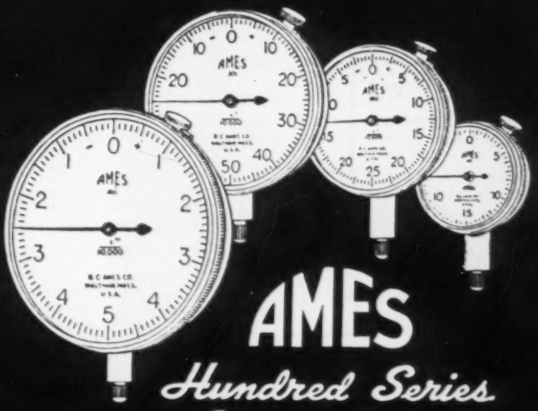

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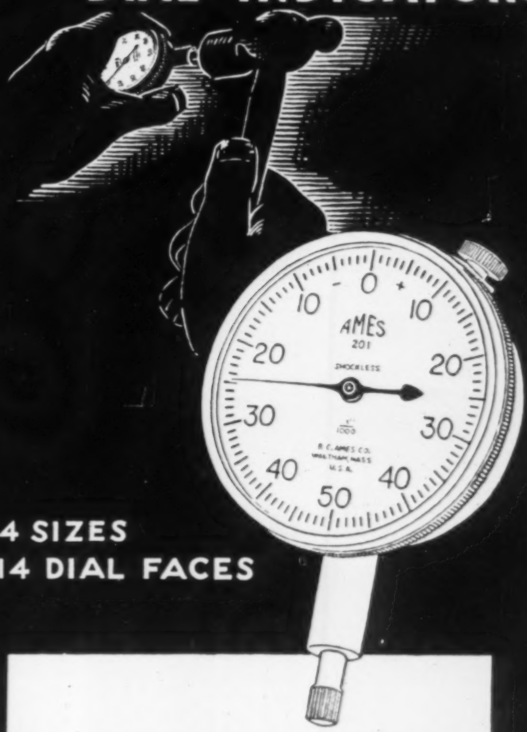

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    - 2. Classes of fit
  - (e) Gages
    - 1. Explain and illustrate tolerances
    - 2. Classify W, X, Y, Z
    - 3. Go and Not Go
    - 4. Work out complete set of gages for [illegible] and fema part
    - 5. Point out some problems that arise
- B. Equipment
  - I. Gage Blocks
    - (a) Historical background
    - (b) Manufacture
    - (c) Three points (size, parallel, flat)
    - (d) Wringing
    - (e) Caution against scoring
    - (f) Stress value
    - (g) Show how to figure size
  - II. Dial Indicator (test)
    - (a) Explain construction
    - (b) Explain use
    - (c) How to mount
    - (d) Emphasize angular error
  - III. Vernier Instruments
    - (a) Discuss use and limitations
    - (b) Show principle and explain how to read
    - (c) Have students read various settings
  - IV. Miscellaneous General Laboratory Equipment
    - (a) Optical comparators
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- C. Inspection
  - I. Measuring outside dimensions
    - (a) Micrometers
      - 1. Describe assembly
      - 2. Explain scale
      - 3. Adjustment
      - 4. Proper use
      - 5. Have class read settings
      - 6. Discuss "feel"
    - (b) Supermicrometer
    - (c) Comparators
      - 1. Explain instruments
      - 2. Discuss use and cautions
  - II. Measuring Inside Dimensions
    - (a) Dial Bore
      - 1. How to use
    - (b) Inside micrometers (two kinds)
    - (c) Bevel parallels
    - (d) Inside caliper
    - (e) Telescope gages
    - (f) Blocks and accessories
    - (g) Blocks and accessories
  - III. Measuring Screw Threads
    - (a) Pitch diameter (three-wire method)
    - (b) Lead and form
    - (c) Calculations
  - IV. Special Problems

ELECTRIC GAGING METHODS

(Continued from page 265)

single longitudinal member of the gage is replaceable, an is made of the same material as the specimen being teste Temperature change will therefore change the length o the specimen and the gage equally, but will not change th spacing of the electrode plates. The dimensions of the plate and their overlap will be changed slightly, but these caus a negligible capacitance change. A gage having the sam thermal expansion characteristic as the specimen will giv indications proportional to the stress in a restrained speci men, rather than the true strain. In most instances this i a desirable characteristic.

Instability in electric circuits is reduced by care in desig and in construction, just as with pick-up devices. Certai types of circuits are less susceptible to errors from thes sources than are others.

In a system in which the tuning of one circuit with respec to another is the criterion of measurement, any facto causing such a change in tuning will appear to the observe just as would a change in the magnitude being measure An increase in the resonant frequency of one circuit cann be distinguished from a decrease in the resonant frequen of the other. Therefore, unless both circuits can be mad absolutely stable—entirely unaffected by anything exce

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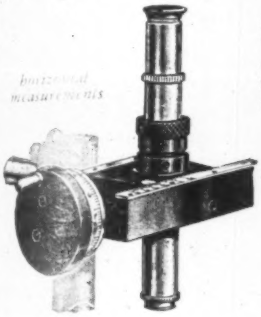

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When used with the various types of support bases available they can be used as small comparators for horizontal linear measurements (Fig. 1).

The microscope mounted parallel to the slide permits depth measurements and micrometer focusing (Fig. 2).

Fig. 1

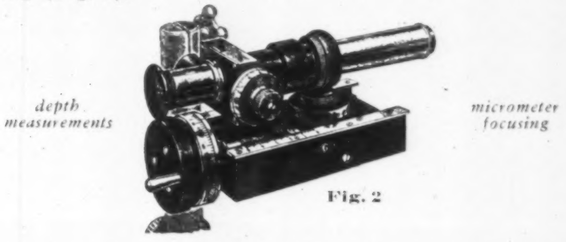

Fig. 2

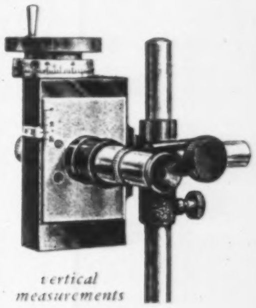

Fig. 3

Vertical orientation permits use as a small cathetometer for vertical linear measurements (Fig. 3). Interchangeability of microscope objectives and eyepieces permits a wide selection of magnifications.

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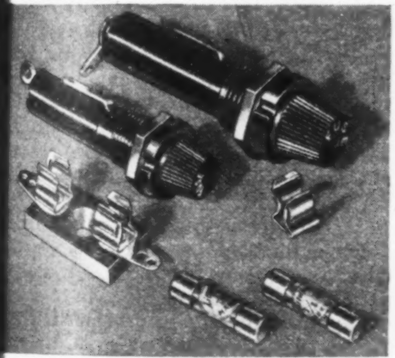

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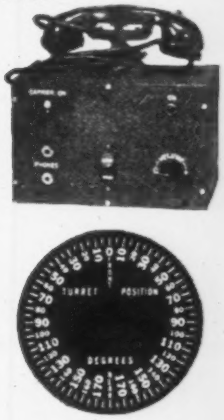

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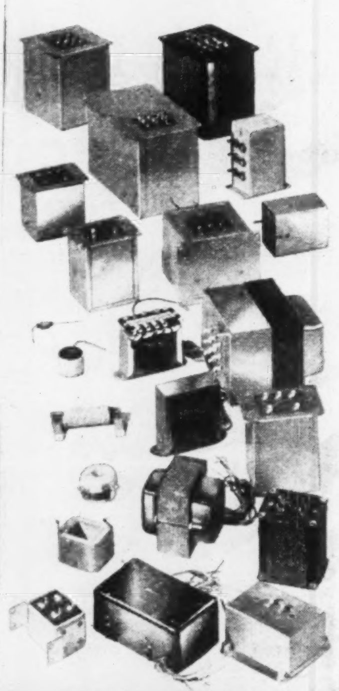

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change in gage capacitance—it is necessary to make th so nearly alike that such changes as must occur affect bo alike. Then, since the difference between them is the crite ion, the errors still occurring cannot be of the first orde and can be made so small as to be negligible. In his ear work, Whiddington used this principle.[21] In at least o recent application of the Whiddington circuit, careful ele trical design and the use of methods of compensation sim lar to those mentioned here have produced a stable fie instrument having a high sensitivity.[58] In another type instrument involving coupled resonant circuits, piezoelectr crystal control of frequency was employed.[59].

Methods are available for constructing capacitors, ind tors, and resistors which will experience little change value over long periods of time, or with change in temper ture and other ambient conditions.[60, 61, 62]

In general, greatest overall stability is possible in t bridge-type circuits; in them the entire circuit, from pick- to indicating device, can often be made symmetrical. It practicable to introduce compensation for changes in t capacitance and the power factor of the connecting cable Where long leads are required, however, other types of gag are usually more efficient. Capacitance-type gages have i herently high impedance, and because of constructional di ficulties, it is more difficult to incorporate high stability such a circuit than in one having lower impedance. Uni having impedance-changing devices built within the pick- case have been used, with connecting cables hundreds feet long, but such systems are somewhat complicated.

ACCURACY

The accuracy of a measurement is a function of all erro present; the actual sources of errors (except errors of o servation, which may be called "mistakes") reside withi the instrument or system, but the effects which produ errors may be initiated by external phenomena. A perfe system would contain no sources of error—and would b entirely unaffected by external phenomena excepting thos which are being measured.*

Gaging systems are subject to two classes of errors *Random errors* may arise from friction, etc.; they invari ably impair reproducibility. *Systematic errors* may aris from either mechanical or electrical defects; they do no always impair reproducibility. In capacitative systems th electric circuits, because of their characteristically high im pedance, are subject to both classes of errors.

Most of the random errors occurring in a capacitativ gaging system originate in the pick-up. The gaging elemen (that portion of the pick-up which converts the mechanica change into an electrical change) should be so constructe as to permit no mechanical hysteresis. Moving parts shoul be supported by elastic suspensions, rather than with sliding or pivoted joints. The effect of friction (as in the strai gage shown in Fig. 33) is to introduce small irregularitie in the characteristic curve for the instrument; no matte how good the bearing surfaces, some mechanical hysteresi will occur. When elastic suspensions are used, they shoul be so designed as to minimize the stress developed withi them; no material has yet been developed which is perfectl elastic over an extended range. The same precautions mus be applied to the other parts of the pick-up—the adjustin

---

(58) A. Lindblad and D. Malmquist. A New Static Gravity Meter and its Use in Ore Prospecting. *Ingeniörs vetenskaps akademiens Handlingar No. 146,* 52 pages. Stockholm, 1938.

(59) John C. Lilly. The Electrical-capacitance-type Diaphrag Manometer. *Review of Scientific Instruments,* Vol. 13, 1942, page 34-36.

(60) H. A. Thomas. Coils and Condensers of Negligible Temperature Coefficient. *Journal of Scientific Instruments* (London) Vol. 14, 1937, pages 221-227.

(61) W. H. F. Griffiths. The Temperature Compensation of Condensers. *Wireless Engineer,* Vol. 19, 1942, pages 101-111, 148-15

(62) Bernard Hague. Alternating Current Bridge Methods. Pi man (London), 1938. 600 pages. Chapter 3.

*For a detailed discussion of accuracy and the types of erro in measuring devices, refer to "Fundamentals of Instrumentatio by M. F. Behar (Instruments Publishing Co., Pittsburgh, 193 Chapter II, pages 27 to 46. Much of this material appeared serial form in *Instruments* during the year 1930.

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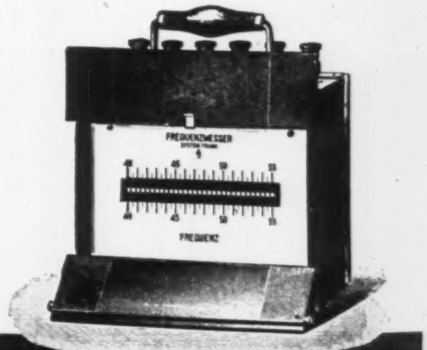

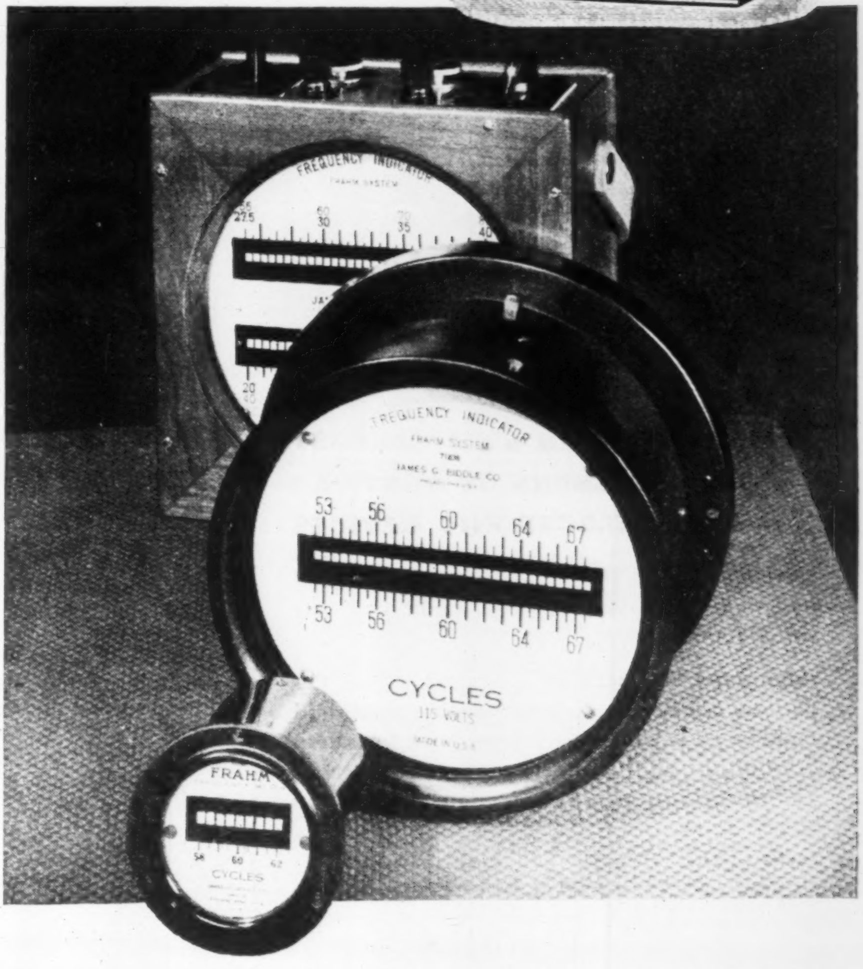

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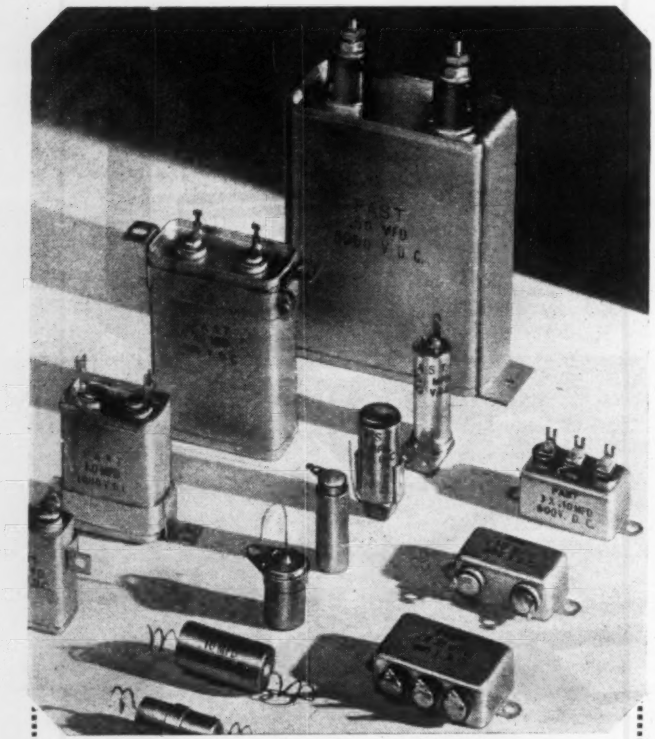

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devices and the facilities for attachment to the specimen.

In all those circuits in which the cable capacitance becomes a part of the gage circuit, further precautions must be taken. These have been listed in the descriptions of the electric circuits.

Two sources of error peculiar to those systems employing electronic amplification are amplifier noise and amplifier distortion. Noise is usually the result of too great amplification. Distortion in amplifiers usually is caused by improper adjustment of electric circuits. Proper design and adjustment of the oscillating electric circuits will make possible the use of less-than-perfect power supplies.[21,58] Proper design and application of the gaging element will provide greater gage output and will require less amplification.

If the presence and magnitude of an error is known, the appropriate correction can be made, and thus for all practical purposes the error is eliminated. If in addition some method is provided to change the response of the instrument easily, it becomes a simple matter to check the instrument at frequent intervals and to apply the necessary correction. These facilities are easily provided in electric gaging systems.

Most capacitance-type pick-ups are designed to be transferred from one location to another—to be calibrated experimentally as often as desired. It is essential that means be provided for adjusting the pick-up *in situ* to correspond to the conditions under which it was calibrated. If the calibration curve for the instrument is linear, separate adjusting capacitors can be employed.

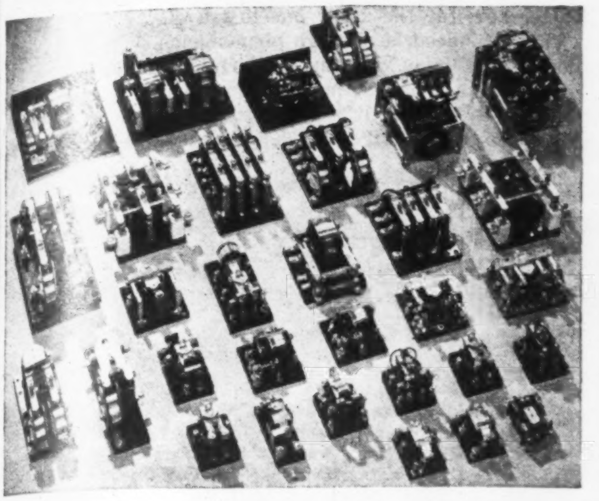
The procedure then is to install the calibrated pick-up and to adjust it (without making any change in the associated electric circuit) until the deflection assumed by the indicating instrument is the same as that during the calibration. This assures that the operating conditions are the same as those during the calibration. If the calibration curve is not linear, the adjustment must be made in the gaging element rather than with separate adjusting capacitors; but, once adjusted, the operation of the circuit will be within the same portion of the characteristic curve as was the calibration.

Over long periods of time one may expect greater changes in the characteristics of the electrical than the mechanical components of the gaging system. Such changes can be detected and compensated if a small fixed capacitor is installed with a switching device so that it can at any time be connected to shunt the pick-up capacitance.[22,58] If at any time the deflection thus produced is not equal to that produced at the time of calibration, the circuit should be adjusted. If an amplifier is used, such adjustment requires only the manipulation of the gain control; in other circuits the adjustment is conveniently made by a shunt to the indicating instrument. With systems which must operate unattended for long periods of time, it is convenient to install such a fixed capacitor and a switching device which will make the required connection at intervals—for example for a period of one second once each hour. If any changes in performance do occur, such an hourly check will disclose the fact and provide the data necessary for correction of the recorded data.

ELECTRON TUBE PRINCIPLES

(Continued from page 272)

however, especially if it were some distance away, since it is quite obvious that the energy in the wave decreases rapidly with the distance from the original splash. Yet, in the photoelectric effect, the ejected electron is knocked out of the metal at exactly the same speed as the electron which originally produced the radiation. In Fig. 111B, for example, is shown an x-ray tube; in this tube a primary electron traveling say at 25,000 miles per second impinges on the target thus producing an x-ray. This x-ray is directed upon another metal plate outside of the tube where by photoelectric action it releases an electron (called secondary emission). Now, strange to say, this secondary electron will be ejected at exactly the same speed as the primary electron, i.e., at 25,000 miles per second. And this is true no



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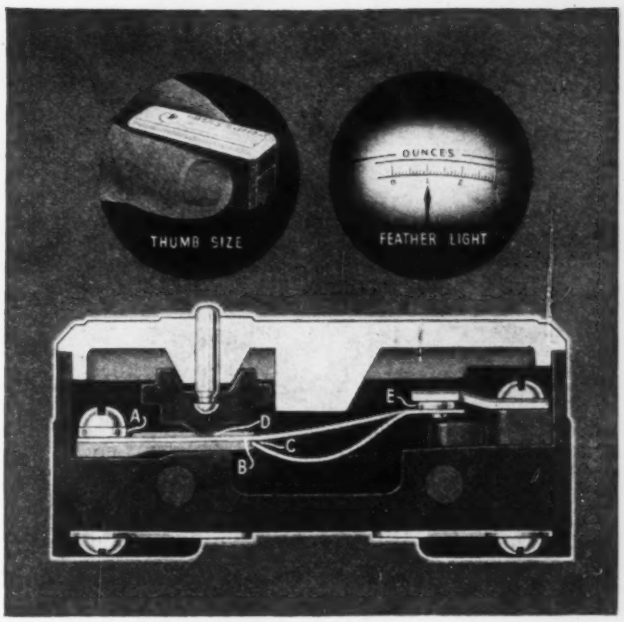

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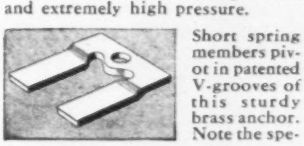

The beryllium-copper spring is made in one piece. It is gauged to an accurate .0085" thickness; has high resistance to fatigue. Ends of compression members are finished to provide an extremely low friction bearing. Contact end of the spring is fitted with a riveted radius type contact of 99.95% fine silver. It moves at a speed of 3/1000ths to 5/1000ths of a second with a rolling action and extremely high pressure.

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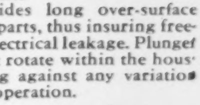

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If you would like to know more about the Micro Switch, send for the two Handbook-Catalogs illustrated here—No. 60, which covers Micro Switches in general; and No. 70 which deals with specific Micro Switches for use in aircraft.

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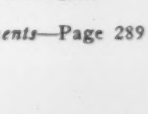

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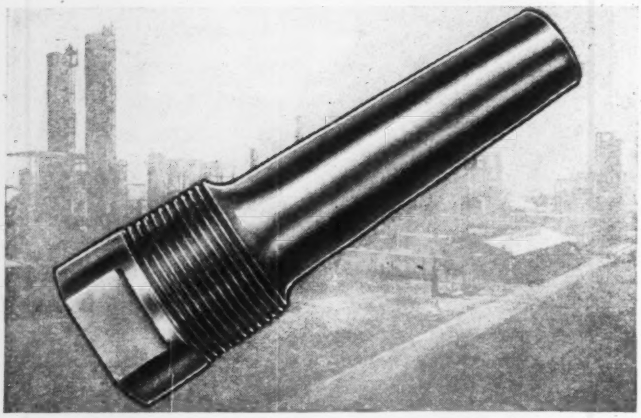

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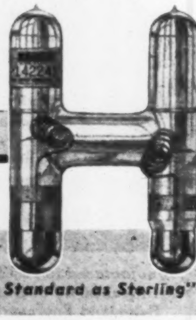

matter how far the x-ray has to travel.

This is, indeed, a strange phenomenon. It is the same as though a lifebuoy were dropped from a height of ten feet in New York harbor and the resulting wave traveling across the Atlantic lifted a similar lifebuoy 10 ft. out of the water at Brest, France. This sounds preposterous, does it not? Yet, that is exactly what happens in the case of the photoelectron. In the photoelectric effect, the speed of the ejected electron is always a function of the frequency of the radiation causing its emission.

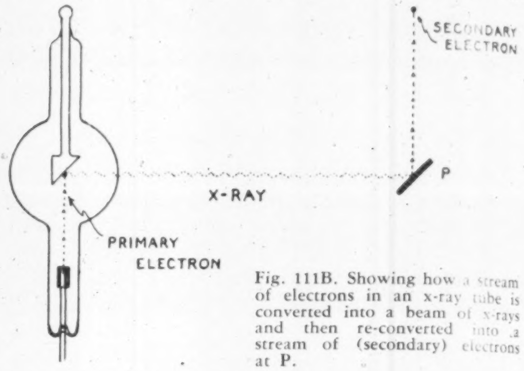

Fig. 111B. Showing how a stream of electrons in an x-ray tube is converted into a beam of x-rays and then re-converted into a stream of (secondary) electrons at P.

It was this strange action which formed the basis of Einstein's famous paper in 1905 in which he suggested that the general phenomenon of the conversion of light energy could be better understood on the assumption that the energy of light radiation was not distributed continuously in space, as assumed by the wave theory. As radiation spread outward from a source he imagined it to remain localized in small bundles or energy quanta, which became further and further apart as they receded from the source while, individually, each bundle remained unchanged.

It is needless here to recount the subsequent experimentation in this field since Einstein's bold suggestions, but all the work done since that time has only confirmed the validity of his idea. And it is on this basis that the photoelectric effect is explained today. Radiant energy (light, x-rays, heat, ultraviolet rays, etc.) is assumed to consist of particles or *quanta* which travel through space, unchanged, undiminished in strength. When these light quanta encounter matter they give up either all of their energy or none at all. They cannot part with only a portion of the energy involved. The energy involved in each light quantum is a function of the frequency and, as explained before, is equal to $h\nu$ where h is Planck's constant and ν is the frequency of the radiation. The light quanta are called *photons*.

The photoelectric effect, therefore, involves the interchange of energy between photons and electrons. And, because the energy of the photon is dependent upon the frequency of the radiation, the photoelectric effect also is dependent upon the frequency. This explains the color sensitivity of the phototube, since color is a manifestation of frequency. This, however, is a matter which will be discussed later.

We have endeavored here to present briefly some of the more important theoretical considerations which underlie photoelectric action. These facts do not have to be understood if one is only casually interested in the application of phototubes, but they provide a rich background for a more thorough appreciation of the action and the possibilities of photoelectric devices. Now we shall consider the effect of these principles upon the characteristics of the phototube.

CHAPTER XVII

OPERATION AND CHARACTERISTICS OF PHOTOTUBES

The curious relation between the frequency of the incident light and the speed of the ejected electron in the photoelectric effect which was described in the preceding chapter has an important bearing upon the application of the phototube, for it provides the latter with a color-sensitive response characteristic. This sounds rather "high hat" but it is only the technical way of saying that the

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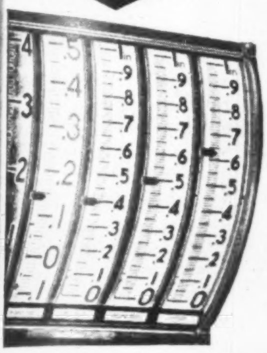

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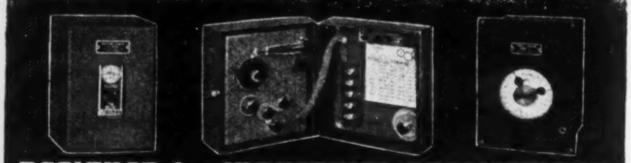

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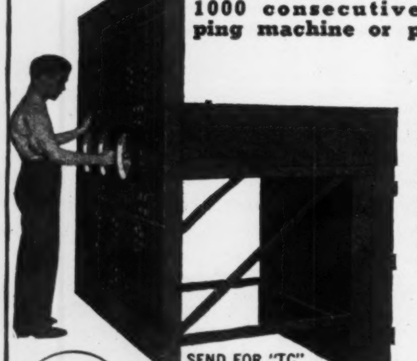

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See page 303

phototube is able to distinguish between light of different colors, just as the human eye does. Thus in the sorting of cigars, a phototube can be mounted in front of a small conveyor carrying the cigars so that if a cigar of a lighter or darker shade of brown than that of the normal run happens to pass by, the phototube would instantly detect it and through a system of relays and control apparatus cause that "off-color" cigar to be removed from the conveyor. Naturally, this ability of the phototube to distinguish between light of different color is one of its most valuable characteristics; for one thing, it provides us with a means of matching colors far more accurate than anything we have known before.

This aspect of photoelectric phenomena is very much like that of a photoelectric plate or film. Even those not seriously addicted to amateur photography know that a photographic plate will be "spoiled" if exposed to even very weak white light for a brief instant, whereas that same plate can be safely handled in the relatively strong red light of the photographic dark-room. In the same way a phototube can be made which is enormously more sensitive to, say, blue or green light than it is to red light: all the red light in the world would not actuate such a tube! Other phototubes are made which will not respond to visible light at all but which are highly sensitive in the ultraviolet region.

The difference in the color response of various phototubes, as may be suspected, is due to differences in the cathode surface. As was pointed out in an earlier chapter, some substances emit electrons under the action of light more easily than others; some substances require light of relatively high frequency (ultraviolet light for example) for the emission of electrons while other substances give copious emission with light of relatively low frequency. Such substances naturally would be used on the cathode surface of a tube intended to respond to red or yellow light.

The physical principles underlying this selective action are quite complicated and involve an intimate knowledge of the forces which hold the atoms and electrons in various materials together. As was disclosed in the preceding chapter, the radiant energy travels through space in quanta, or bundles, each of which can be handed over to matter in its entirety but not in part. If, in a specific case, the energy in a quantum is equal to the force which holds an electron in place, this quantum will be able to knock such an electron out of the material in which it resides.

The forces with which electrons are held in place in various substances varies widely, just as the forces with which atoms and molecules are held in place vary widely in different materials. The energy in light, we have learned, is also a variable, increasing with the frequency of the radiation. Therefore, it is obvious that if the frequency of the radiation is high enough, the energy will be sufficient to overcome the electrical forces between the electrons and atoms of the material exposed and emission will take place. This is perhaps a crude way of explaining it but, in principle, this is essentially what takes place.

Now, it becomes evident why certain substances are much more suitable than others for photoelectric emission. Obviously, those materials in which there are a large number of free electrons more or less loosely bound will provide high emission; the metals, for example, would be expected to be better emitters than the non-metals and this, actually, is the case. Even among the metals, however, there is considerable difference in the forces holding the electrons in place and it has been found that the alkali metals provide the greatest emission with the lowest radiation quanta. These, therefore, are the metals most suitable for photoelectric work.

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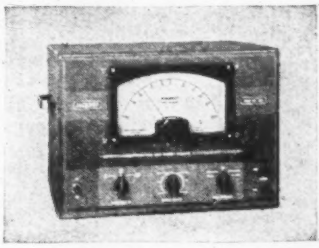

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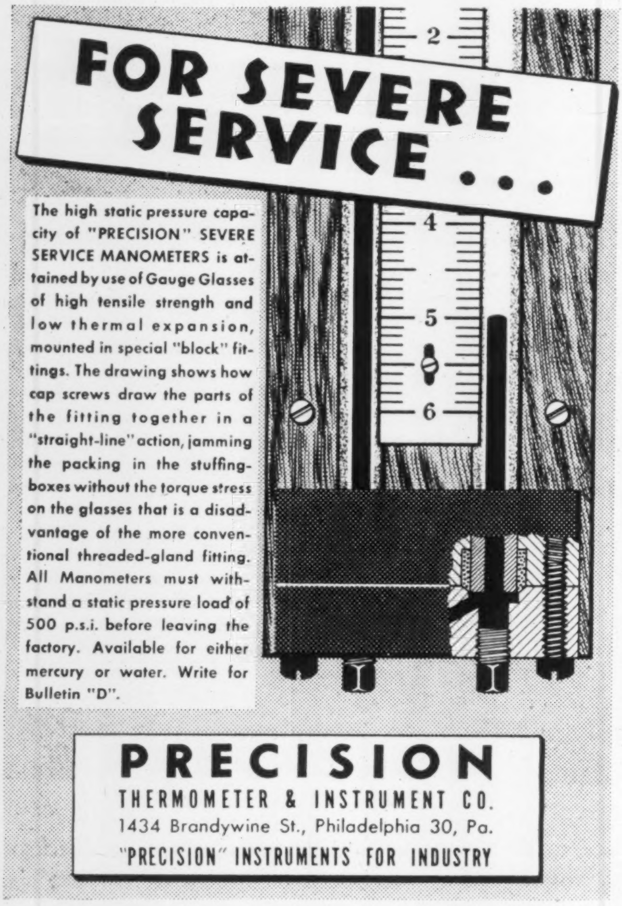

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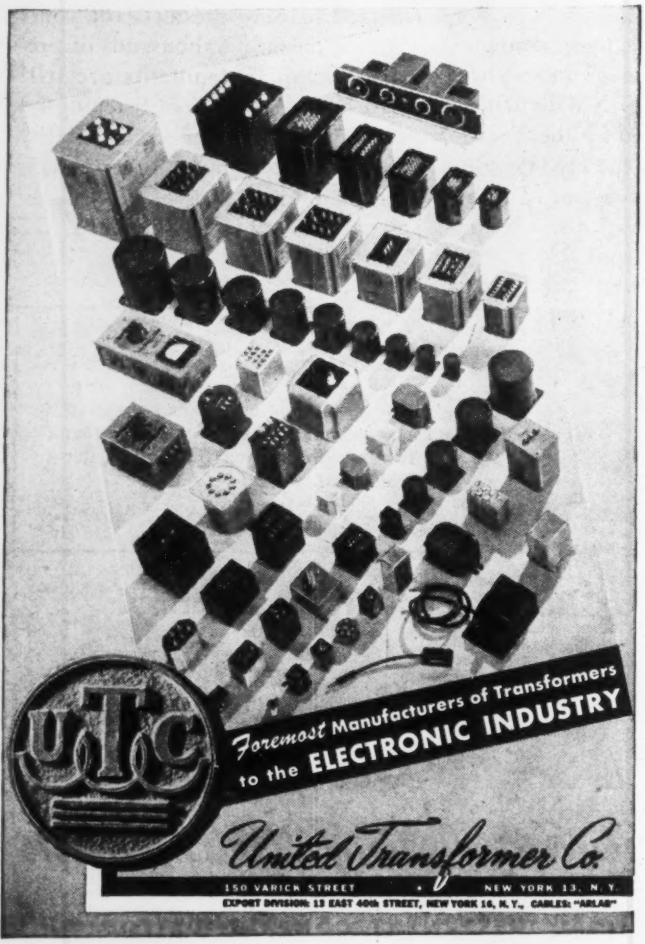

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to be related to the position of the metal in the periodic table. The large number of photoelectrons released from metals is attributed to the presence of the free electrons within the metals. These free electrons, which were discussed in Chapter I, are relatively free to move within the metal lattice and are responsible for the high electrical conductivity of metals. A smaller surface photoelectric effect is also found for insulators but the absence of conductivity makes it difficult to obtain continuous emission since as a result of the loss of electrons at the surface, the insulator soon assumes a positive charge.

It is not necessary here to enter into a technical discussion of the theory of photoelectric emission but one or two facts should be mentioned. One of these is a factor, usually referred to as "surface work." This is the term given to the amount of work required to enable an electron to overcome the forces which exist at the boundary of any surface. It might be compared to the work required by a molecule of water to overcome the surface tension of the liquid in the ordinary process of evaporation. As is well-known, the surface of any liquid is characterized by a surface tension which tends to keep the molecules of the liquid from leaving the liquid. When such a liquid is heated, the increased kinetic energy given to the molecules enables some of them—those very close to the surface—to escape into the space above.

A similar condition exists at the surface of a metal so far as electronic emission is concerned. Whether the emission is thermionic or photoelectric, before an electron can be emitted, it must acquire sufficient kinetic energy to overcome the surface tension of the metal. It is evident, therefore, that metals having a low surface tension, or *work function* as it is called, are most suitable for photoelectric work.

The surface work of the principal alkali metals used in photoelectric work is given as follows:

Lithium	.....2.36 volts	Potassium	...1.55 volts
Sodium	......1.82 volts	Rubidium	...1.45 volts
Caesium	........1.36 volts		

From this it will be apparent that unless for some special reason it is not feasible to do so, caesium should be used for the cathode of a phototube. Its surface work is so low that quanta of little energy content may be used to excite it and this means that it will be sensitive to the red end of the spectrum. Today caesium is used more than any other for phototubes responding to ordinary light.

There are a number of other factors which determine the performance of a phototube; aside from the metal used the character of the surface itself has an important bearing. Today the plain metals are rarely used for the cathode surface. They are nearly always used in the "sensitized" or thin film condition. There are two main processes of sensitization. The first process was devised more than forty years ago by Elster and Geitel (who had made the first vacuum phototubes ~~in 1890~~) and for some twenty years it was used in all emission tubes adapted for the visible spectrum. It consisted in making the metal the cathode of a glow discharge in hydrogen. It is accompanied by a change in the appearance of the surface; thus the white metallic potassium becomes matt and assumes a characteristic blue-green color. The increase in sensitivity obtained by this "flashing" process is quite remarkable, as is shown by the curve in Fig. 112. The second process, developed during the

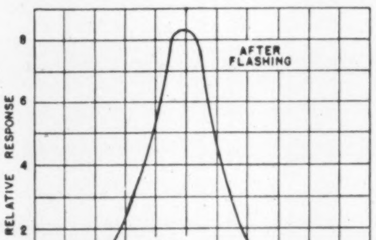

Fig. 112. Curves showing the effects of "flashing" upon the sensitivity of the cathode surface.

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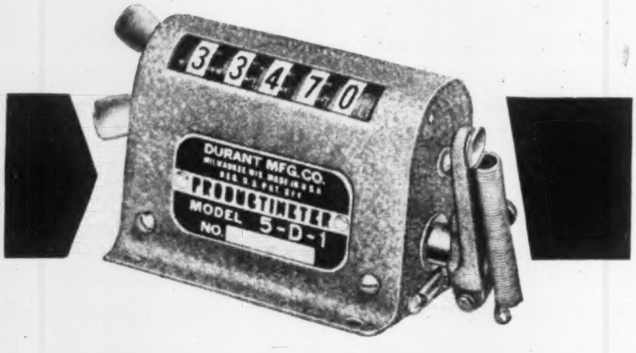

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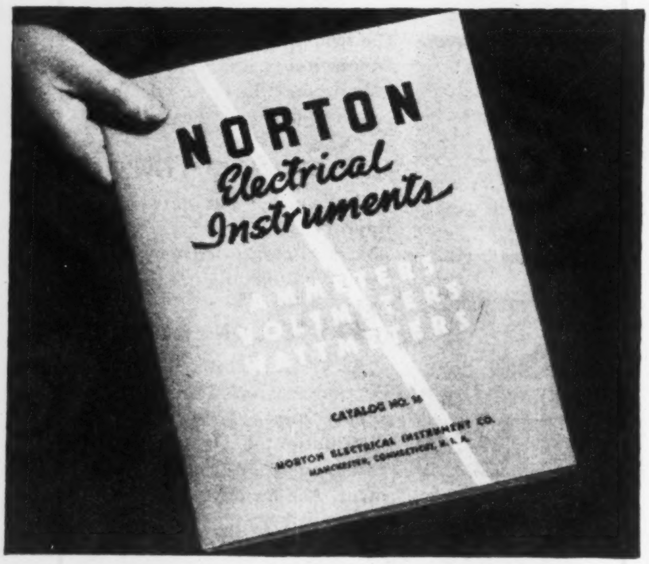

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last eight years, consists in exposing the metal for a short time to the action of vapors containing oxygen or sulphur.

There are other processes or preparing cathode surfaces by the deposition of thin films of alkali metals upon sensitive metals (platinum for example) or upon the glass wall of the tube itself. Pure sodium may be deposited upon the inside of a tube by passing an electrolytic current right through the glass. The bulb is immersed in a molten bath of sodium nitrate; the current flowing from the bath through the glass (which must be soda glass) deposits the pure sodium on the inner wall of the bulb. Pure sodium, however, is not a very efficient photoelectric emitter so that cells prepared in this manner are not sensitive, though they are very permanent in their performance.

So much for the formation of the cathode surfaces. These matters do not concern the ordinary use of the phototube since they involve only design and manufacturing considerations but they are of general interest in that they give some insight into the scientific basis for the existence of the phototube. The phototube is a simple enough device in its make-up but it is quite apparent even from the limited treatment of it given here that its design is based upon profound physical, chemical and electrical knowledge.* It is at once the product as well as an important tool of scientific research.

The spectral distribution curves for the alkali metals are shown in Fig. 113 which gives the relative spectral response as a function of the wave-length of the incident light. Caesium may be seen to possess the longest wave-length sensitivity, even to red radiation.

Where sensitivity in the ultraviolet region is desired, various metal surfaces whose work function thresholds lie within that region can be used. It is frequently advisable that an ultraviolet sensitive phototube be insensitive to visible radiation; hence the use of such metals as tantalum, titanium and thorium. The spectral curves for these metals are shown in Fig. 114.

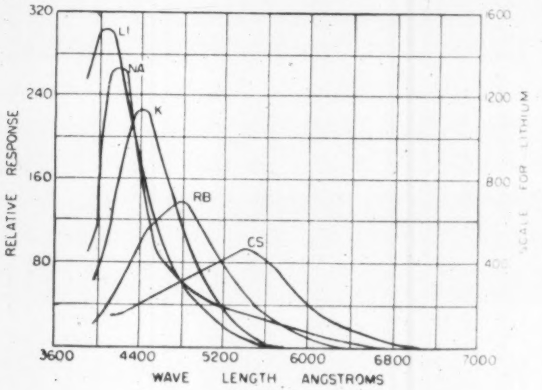

Fig. 113.

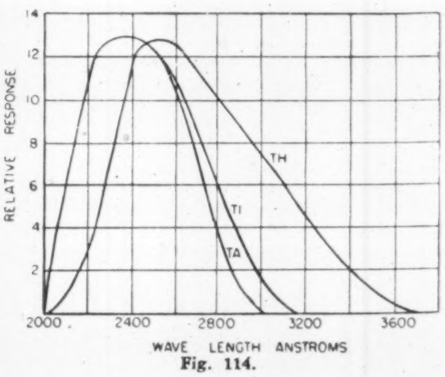

Fig. 114.

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*Those interested in pursuing the subject of phototube design further are referred to "Photoelectric Cells" by Campbell and Ritchie, (Pitman Publishing Corp., New York) and to the chapters on phototubes and photoelectric phenomena in Morecroft's "Electron Tubes" (John Wiley & Sons, Inc., New York). See also "Phototubes and Photocells" by L. R. Koller, *Instruments*, Jan. 1938, page 51; also "A Review of the Development of Sensitive Phototubes" by Alan M. Glover, *Proceedings of the I.R.E.*, August 1941, pages 413-423.

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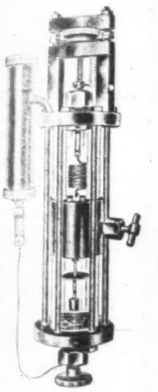

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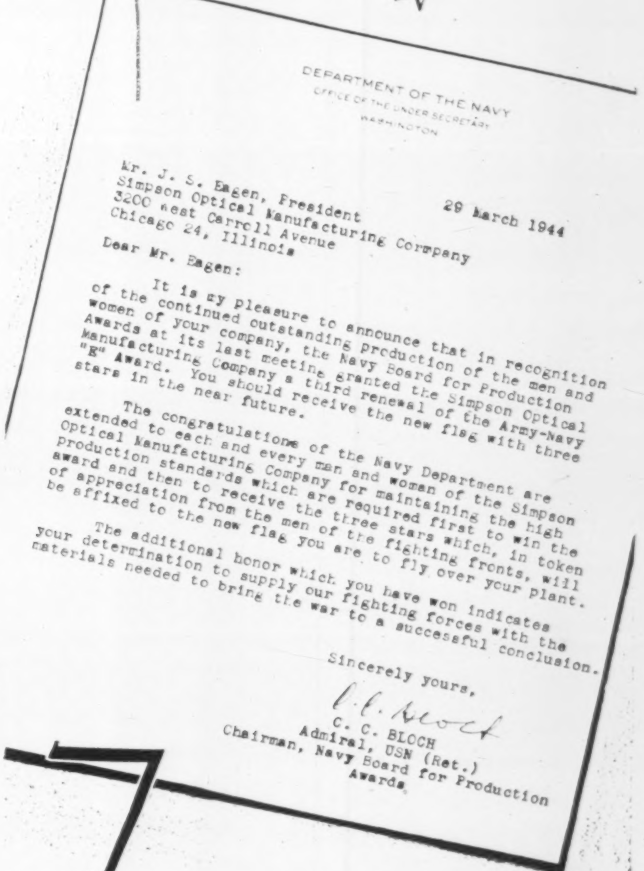

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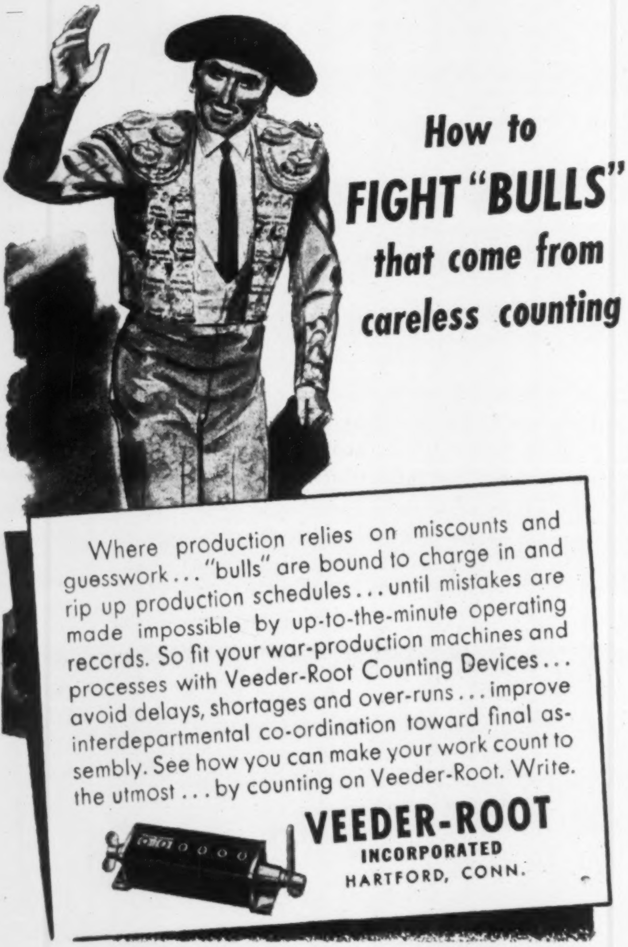

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Now, let us see what this color sensitivity characteristic of the phototube actually does to the tube's performance in practice. As might be expected, the color sensitivity of the phototube is quite different from that of the human eye and, of course, it varies widely depending upon the type of cathode surface used. Certain tubes are designed for use in the ultraviolet region while others are suitable for use only in the red or infrared. Just as it is possible to make photographic plates which are sensitive to certain regions of the spectrum, so also is it possible to make phototubes sensitive to some particular part of the spectrum. Fundamentally, the color response is determined by the cathode surface but a standard tube can often be provided with a light filter to effect the same purpose.

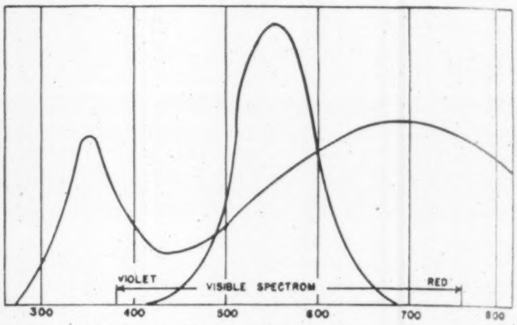

Fig. 115. Sensitivity curve of a certain group of phototubes compared to the sensitivity curve of the human eye.

In Fig. 115 is shown a curve representing the color sensitivity of a number of well-known commercial phototubes together with another curve on the same chart and drawn to the same scale, representing the sensitivity of the human eye. As will be seen there is little similarity between these two curves, the phototube having an entirely different characteristic from that of the eye. It is highly sensitive in the red region of the spectrum and also in the ultraviolet.

Comparing these two curves, the one for the phototube and the one for the eye, at first it might be assumed that this difference in shape might be unfavorable to the use of the tube as a device for the measurement of color. If one stops to think about the matter, however, it will be apparent that as far as the phototube is concerned, this type of curve is very well suited to the use of color measurement, for it will be noted that except for those regions in the extreme violet and red, the curve is linear. Consequently, if the color of the incident light is varied uniformly from violet to red, through the entire range of the spectrum, and assuming that the intensity of illumination remains the same, there will be a gradual increase in the current output of the tubes which can be interpreted in terms of color or wave-length. This is purely theoretical. Colorimeters using the phototube are not as simple as this but the principle will be obvious.

For most industrial uses, the ability of a phototube to discriminate between light of different color is of less importance than high sensitivity in some particular region of the spectrum either within or outside of the visible range. In sorting operations such as the inspection of cigars referred to above, color discrimination is necessary but only to a limited degree. In most instances all that is necessary is that the tube be responsive to changes in light in-

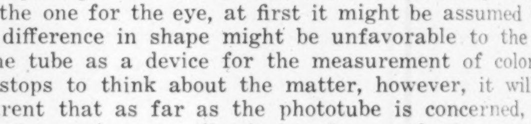

Fig. 116. The simple elements of a photoelectric smoke indicator and alarm.

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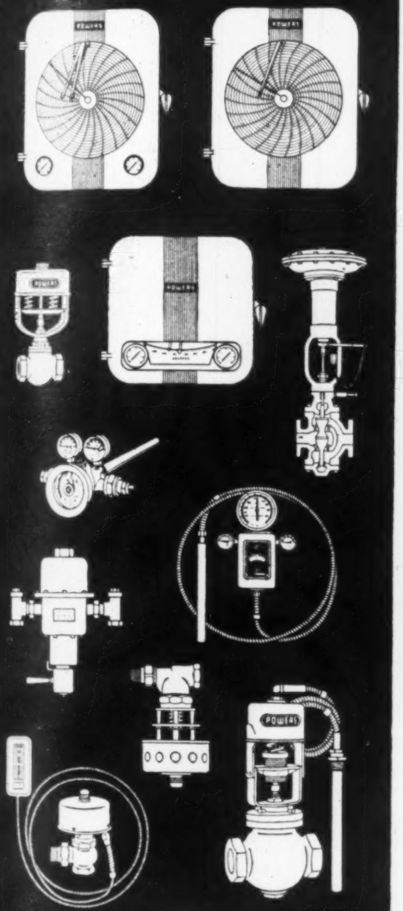

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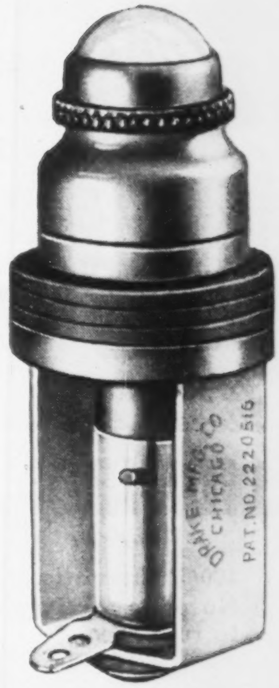

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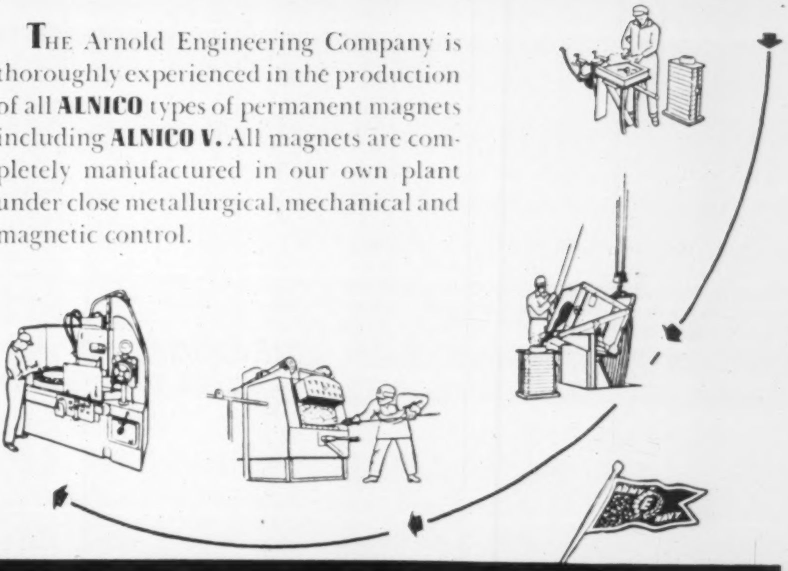

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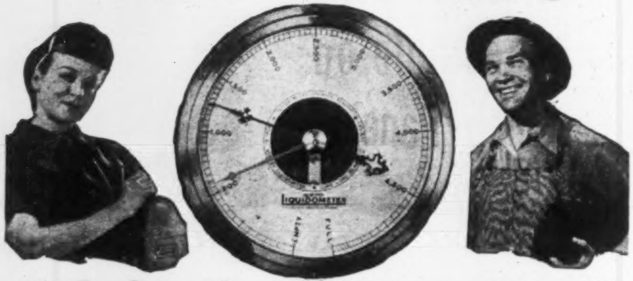

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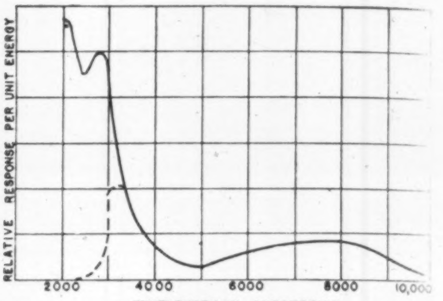

Fig. 117. Curve showing the effect of the material of the envelope of a phototube. The full curve shows the frequency response curve of a tube with a quartz envelope while the dotted portion shows how the sensitivity drops off at the high frequency end if a glass tube is substituted for the quartz tube.

tensity. Thus in a smoke indicator, a phototube tube installed in the side of a breeching or stack responds to the varying intensity of a beam of light transmitted across the smoke flue. The fundamental principle of such a device is shown in Fig. 116. In this case the intensity of the smoke is indicated by a milliammeter (calibrated in terms of smoke density) in the plate circuit of the vacuum-tube amplifier which is provided with contacts for operating an alarm bell when the smoke density exceeds a predetermined limit.

In cases where a phototube must respond to ultraviolet radiation it is not only necessary to provide a cathode surface with the proper characteristics, but the proper type of glass envelope must also be provided. In Fig. 117 is shown a curve representing the color sensitivity of a phototube designed to give a high current output when exposed to ultraviolet radiation. The tube, however, must be made of quartz if this ultraviolet sensitivity is to be attained, since quartz will transmit ultraviolet radiation. If this same tube is provided with a glass envelope, the response curve will be that shown by the dotted portion. The glass absorbs nearly all of the ultra-violet radiation, permitting little light energy from reaching the cathode surface. Ultraviolet phototubes are useful in scientific measurement work and in protective systems against burglary.

These few instances will serve to indicate the nature of the problem involved in the application of the phototube. A knowledge of the characteristics of the phototube is essential as is also a general understanding of its operation.

Thus far, we have mentioned only phototubes of what is known as the photoemissive class—those of the high-vacuum type as well as the gas-filled. There are available, however, other light sensitive devices, both tubes and cells, which operate on a different principle from those described.

In general, there are two other types of light-sensitive devices, one group known as photoconductive devices and the other, photovoltaic devices. Of the photoconductive group, the selenium cell or tube is the most prominent example. As is well-known, selenium has the peculiar property when placed in an electric circuit of changing its resistance in accordance with the intensity of light falling on it. Normally, selenium exhibits a high resistance to the flow of electricity but when it is illuminated, this resistance decreases. The ratio between the dark and light resistance may be as much as 10 to 25 times.

This property of selenium has been known for many years, since 1872 in fact, but until recently little success was had in adapting it for use as a light-sensitive control device. By a special technique of forming the selenium surface in a vacuum and annealing it in a dry, inert gas, many of the earlier difficulties have been removed and a stable, useful selenium tube is commercially available today. Its color response compares favorably with many of the photoemissive tubes but its speed of response is considerably slower. Whereas the photoemissive tube can respond to variations in light intensity of millions of cycles per second, the photoconductive tube is capable of responding only to changes of tens or hundreds of cycles per second. As actually built, selenium resistance elements are generally sealed up in glass tubes filled with helium or similar gas and have a dark resistance of a megohm or more.

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INSTRUMENT SOCIETIES CALENDAR

City, Society and Secretary			Date	Place	Subject	Speaker
Atlanta	Georgia Society for Measurement & Control	Roger W. Allen, 376 Nelson St., S.W., Atlanta	May 22		To be announced	
Baltimore	Baltimore Industrial Instrumentation Society	C. B. Willnecker, 6732 Danville Ave., Dundalk, Md.				
Chicago	Chicago Society for Measurement & Control	A. J. Butler, 2626 W. 31st Blvd., Chicago				
Cleveland	Cleveland Instrumentation Society	F. G. Meulenberg, DuPont Exp'l Lab.				
Gulf Coast	Gulf Coast Instrument Maintenance Men's Ass'n	T. H. Pierson, 3030 Roberts St., Beaumont, Tex.				
Hartford	Hartford Society for Measurement & Control	Stephen J. Zelle, Whitney Chain & Mfg. Co., Hartford, Conn.				
Kansas City	KC Industrial Instrumentation Society	Gordon H. Burke, Burke Engineering Co.	May 30		To be announced	
Newark	New Jersey Society for Measurement & Control	Robert H. Gray, 84 Centennial Ave., Cranford, N. J.	June 6(B)	Essex House	Electronic Pyrometry	C. O. Fairchild, C. J. Tagliabue Mfg. Co.
New York	New York Society for Measurement & Control	H. R. Kalbfleisch, 114-35 No. Blvd., Flushing, N. Y.	May 31(B)	Building Trades Emp. Ass'n, 2 Park Ave.	The GE Electron Microscope	Dr. C. H. Bachman, GE C
N. Indiana	Northern Indiana Soc. Measurement & Control	R. W. Schreiner, 4 Waltham St. Calumet City, Illinois				
Philadelphia	Philadelphia Society for Instrumentation	J. E. Gambrill, 1317 Spruce St.	May 17(B)	Engineers Club	Instal'n and Oper'n of Differential Flowmeters	L. K. Spink, Foxboro Co.
Pittsburgh	American Society for Measurement & Control	L. M. Susany, c/o Carnegie Institute, 4400 Forbes St., Pgh.	May 22(B)	Roosevelt Hotel	Air-operated Control	J. N. Swarr, Bristol Co.
St. Louis	St. Louis Society for Instrumentation	Gus Holubeck, Union Electric Co., Venice, Ill.				
Toronto	Canadian Society for Measurement & Control	T. C. Agnew, Minneapolis-Honeywell Reg. Co., Toronto				
Washington	Instruments Society of Washington	R. C. Darnell, 2400 "S" St. SE, Wash'n	May 24	Interior Dep't Auditorium	Electrical Recording Instruments	GE Co. speaker

(A)Meeting at 7:30, no dinner. (B)Dinner at 6:30, meeting at 8. (C) Dinner at 7, meeting at 8. (D)Meeting at 8, no dinner.

ATLANTA

The April meeting of the Georgia Society for Measurement & Control was held on the 24th at the Sidney Lanier room of Davison-Paxon Co. Atlanta, had a good attendance and was very instructive and interesting. Mr. Walker of the Westinghouse E.&M. Co. gave a fine illustrated talk on "Upkeep and Service on Motors" as well as a movie film on "Electronics and the Development of Electronic Appliances."

There was a misprint on this page in April: the President's name is

—Howard M. Baker

CHICAGO (CSTC)

[Press release received after April issue was mailed]

4000 enthusiastic and interested engineers, scientists and manufacturers gathered at the Stevens Hotel, March 30th, for the 2nd War Production and related problems Conference sponsored by the Chicago Technical Societies Council.

The Clinic was again held at the request of the WPB and in coöperation with the Board and the Army and Navy.

At the afternoon session John Collyer, Pres. of the B. F. Goodrich Co., gave an illuminating talk on the development of synthetic rubber, facts on the present-day usage and performance and plans for tomorrow.

Rear Admiral Carpender, Ninth Naval District, paid high praise to the conference in the evening speech, in which he reviewed the course of the war in the Pacific.

Purpose of the conference was to expedite the war effort by providing a means for the exchange of mutually-beneficial ideas among engineering, technical and scientific societies, and interested manufacturers in the Chicago area.

In a series of 33 panel sessions, all phases of war production and related problems were discussed. All panel discussions were led by recognized experts in their fields.

The Council is composed of the representatives of 36 societies. Its aims are: (1) to provide a medium for coöperative action by the engineering, technical and scientific societies in the mid-west on matters of mutual interest which are beyond the scope of individual societies or which can be performed better by coöperative action; (2) to provide means for more effective public service by the member societies; and (3) to cultivate greater appreciation by the public of the part which the engineering, technical and scientific professions have contributed to human welfare.

Let's Have News Anyway!

In spite of no meetings in summer, keep your Society in print! Secretaries and Publicity Chairmen (and others) please send me items—even "personals" — to run on this page which belongs to you.

—M. F. Behar, *Editor*

The CSTC is composed of two delegates from each member society including the ASTM, and Chicago Society for Measurement and Control. Those desiring membership or further information should write to K. H. Hobbie, Corresponding Secretary, Chicago Technical Societies Council, care Driver-Harris Co., 1140 W. Washington Blvd., Chicago 7, Ill.

KANSAS CITY

On April 12, a meeting was held at which there was organized the Kansas City Industrial Instrumentation Society. Twenty-four individuals representing seventeen different firms in the Kansas City area attended.

Officers and council were elected as follows: *President*, Wm. A. Reichow, Minn. Honeywell Reg. Co.; *Vice President*, Wm. G. Eargle, Phillips Petroleum Co.; *Secretary-Treasurer*, Gordon H. Burke, Burke Engineering Co.; *Council*, H. B. Manley, J. F. Pritchard & Co.; R. Benninghoven, Republic Flow Meter Co.; E. L. Burnett, Hercules Powder Co.; Lew Mears, Sullivan-Mears Co.; E. A. Thompson, Minn. Honeywell Reg. Co.; E. J. Bumsted, Fluor Corp., Ltd.

On April 26 the first general meeting was held at the Blue Bird Cafeteria, 3215 Troost Avenue. Our Quiz Kids, Paul VanValkenburg of Manning, Maxwell & Moore; Larry Siler, Hercules Powder Co.; Joe Spacek, Aluminum Co. of America; Guy Davis, Phillips Petroleum Co., provided stimulated entertainment and education in answering technical questions from the floor. Our guest speaker, Mr. O. B. Wilson, Industrial Manager Brown Instrument Division, Chicago, did a "bang-up" job in presenting an illustrated talk on "Practical Aspects of Automatic Control."

Monthly meeting will be held the last Tuesday of the month when satisfactory arrangements can be made for said date. Our next meeting is scheduled for May 31st, 7:30 p. m. at the Blue Bird Cafeteria, 3215 Troost Avenue. Our guest speaker will be Mr. C. W. Parsons, Ass't to the Vice President, Republic Flow Meters Co., Chicago, who will talk on "Combustion Control and Instruments."

—Wm. A. Reichow

NEW JERSEY

At the May 2 meeting we deviated from our usual practice of emphasizing industrial plant instrumentation, by having as speaker Mr. C. E. Ohlheiser of American Instrument Co. who covered recent advances in some laboratory applications which have found use in plant laboratories as well as research laboratories. Recent applications of laboratory type equipment in the industrial plant, as contrasted to the plant laboratory, were also covered.

Included in Mr. Ohlheiser's discussion were: basic types of temperature control used in laboratory applications; general designs of baths, ovens and cabinets for close control (application to 0.001°C.); some high-pressure vessels on laboratory applications; development of a micro-metering pump (from 20 cc. per hour up); and a plating thickness meter.

Mr. Ohlheiser discussed several important but little appreciated problems in humidity measurement and control, and his deep personal interest in this subject was quickly evident. A special application of humidity measurement in connection with high-altitude flying proved of interest, and in addition it outlined a new approach to the measurement of relative humidity near the low end of the scale.

The results of our election of officers for the coming year: *President*, E. L. F. Engelhard; Vice-*President,* R. F. Roberts; *Secretary,* R. H. Gray; *Treasurer,* Sid Baran.

—Bob Gray

NEW YORK

At the end of the business session of the March 2 meeting our member Mr. R. Rimbach of the Instruments Publishing Co. spoke about the formation of similar societies in other parts of the country.

Mr. J. A. Forrest of the Bausch & Lomb Optical Co. gave a talk on "New Optical Tools for Research." This lecture was very interesting as the discussion was confined mostly to the application of optical instruments to the various laboratory problems. The results thus obtained were stressed by Mr. Forrest rather than the optical operation of the instrument. Many remained after the talk to ask questions which the speaker willingly answered. —H. R. Kalbfleisch

PHILADELPHIA

Mr. C. E. Mason of the Mason-Neilan Regulator Co. gave a talk at our April Meeting on the "Influence of Line Drop on Valve Characteristics." He traced the development of valve drop characteristics along the same grounds that the piping engineer had evolved pressure drop in terms of feet of pipe or number of fittings. By expressing valve characteristics in terms of a valve coefficient which could be translated in g.p.m. per pound pressure drop, it was possible to consider the valve opening in terms of an orifice, and comparable calculations could be made. He further pointed out that it was not entirely accurate to size control valves in terms of maximum flow and minimum pressure drop, as this was really a hang-over from the old days when line drop was paramount.

His discussion centered around three types of valves: (1) equal percent of logarithmic change of valve area; (2) rectangular or linear change of valve area; (3) "V" port or parabolic change of valve area.

If valve opening area is plotted in percent of maximum on the abscissa, and valve travel as the ordinate, using semi-log paper, it becomes relatively easy to analyze the type of valve required for a definite application. In other words, our Instrument men appreciated that the proper size valve with the proper characteristics could only be determined from such analysis.

There were 31 at dinner and 68 at the meeting.

The Philadelphia Society had its first Annual Dinner Dance at the Hotel Warwick, at which there were approximately 50 in attendance. All of those present at the affair agreed that the Entertainment Committee had made excellent arrangements for our first affair of this kind and are looking forward to its repetition next year.

—J. E. Gambrill

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MACHINE TOOL CONTROL

(Concluded from page 257)

movement of the lathe carriage, and the air filters and pressure reducing valves which supply compressed air to the pneumatic tracer. The monorail track is supported by brackets attached to the lathe pedestals so that the control makes no floor obstruction which would hinder sweepers.

The control power unit consists of a large oil reservoir, a motor-driven oil pump, hydraulic relay valves for feed and contouring action, and directional flow selector valves which provide for setting up the machine to turn, bore or face.

BACKLASH ELIMINATION

Since this control system functions by the regulation of fluid flow in both the pneumatic and the hydraulic systems, there is no backlash or lost motion on either side of the neutral tracer position. Furthermore, the air loading pressure which transmits the requirements for tool positioning is a precise indication of the accuracy with which the cut is progressing. This information is made available to the operator by means of an indicating gage in the air loading pressure system. As long as this gage indicates the neutral loading pressure of 35 lbs./in.², the operator knows that the cutting tool is in position to produce extreme accuracy. If the air loading pressure increases to 37 lbs. or decreases to 33 lbs., the operator knows that the cutting tool is no longer in the position of extreme accuracy, but that an error of 0.001″ has been introduced. By use of this precise continuous visual sizing method or "flying mike" effect, the operator can increase his rate of feed up to the allowed tolerance by watching the indicating gage on the air loading pressure. Adjustments for both the rate of feed and the rate of contouring action are provided so that a maximum rate of production consistent with the required accuracy may be maintained at all times.

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Some of the apparent advantages of the glass gage follow: Glass gages afford visibility in inspection. Glass gages are not subject to corrosion. There is less tendency to gall in some applications. Sense of feel is more pronounced when using glass gages. Because the thermal conductivity of glass is less than steel, body heat of inspectors will not be transmitted so rapidly to the gage to affect gaging dimensions.

Chewing gum, too, is really useful and helpful in these tense times to people who are working on the production front making material for our war effort. But, our Armed Forces have been constantly increasing their demands for Wrigley's Spearmint, Doublemint and Juicy Fruit. It is only natural that we and you both feel that the needs of our fighting men and women come first.

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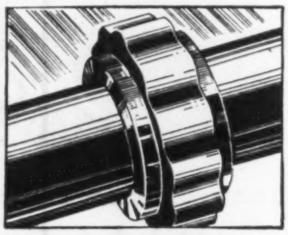
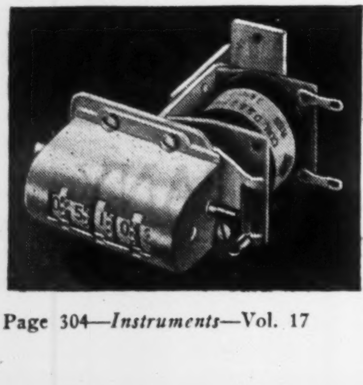
Glass gages are not subject to corrosion or rust



Visual inspection of surface coincident with inspection for size.

Y-113



Correll & Correll High Speed Electric Counter

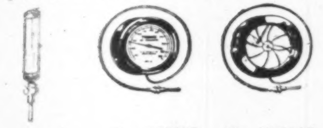
Ideal for all counting and data accumulation work . . . production . . . control . . . developmental . . . psychological . . . etc. Standard voltage is 110 volts 60 cycles, but other voltages from 6 to 220 A.C. or D.C. are available at 75c additional. G&G HiSpeed Electric Counters, $4.10 each FOB factory.

Counter is compact, sturdy, well engineered. Counts up to 700 per minute. Operates on non-reset principle . . . counts to 99,999 and then repeats. Draws only 4 watts. Counter mechanism totally enclosed . . . large figures easily read through plastic window. Mounts and operates in any position. Size 3⅛″ by 3⅛″ by 1⅝″. Cadmium plated. Special bracket to permit mounting at right angles is recommended at 26c extra.

Correll & Correll
CHICAGO HEIGHTS, ILL.

TRERICE

THERMOMETERS



No. A12402½ Industrial
No. M81110 Dial
No. M82115 Recording

TEMPERATURE CONTROLLERS

No. 90000 Self-Operating
No. V85002 Air-Operated Non-Indicating Type
No. M87000 Air-Operated Recording

PRESSURE GAUGES

No. 800 Steel Case
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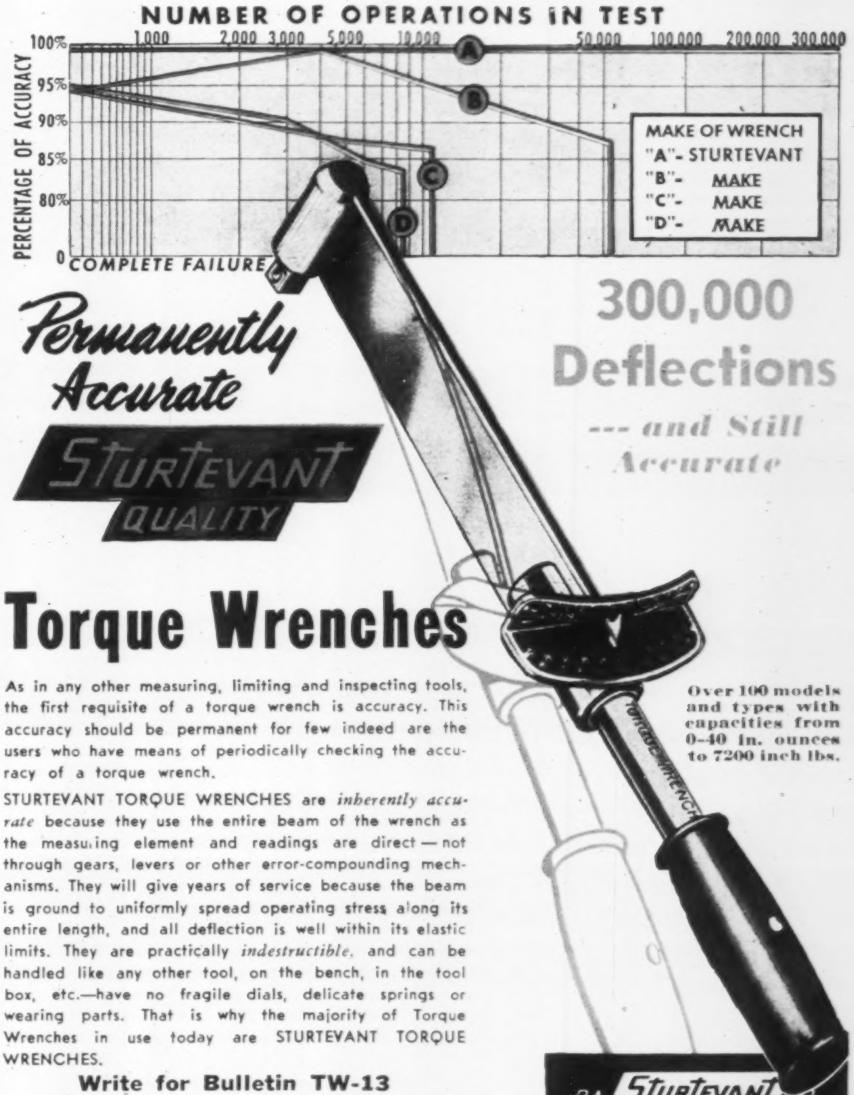

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Torque Wrenches

As in any other measuring, limiting and inspecting tools, the first requisite of a torque wrench is accuracy. This accuracy should be permanent for few indeed are the users who have means of periodically checking the accuracy of a torque wrench.

STURTEVANT TORQUE WRENCHES are *inherently accurate* because they use the entire beam of the wrench as the measuring element and readings are direct — not through gears, levers or other error-compounding mechanisms. They will give years of service because the beam is ground to uniformly spread operating stress along its entire length, and all deflection is well within its elastic limits. They are practically *indestructible*, and can be handled like any other tool, on the bench, in the tool box, etc.—have no fragile dials, delicate springs or wearing parts. That is why the majority of Torque Wrenches in use today are STURTEVANT TORQUE WRENCHES.

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Over 100 models and types with capacities from 0–40 in. ounces to 7200 inch lbs.

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(Appeared serially in *Instruments* from August 1941 to June 1943

By JAMES SPENCER

In charge of Instrument and Relay Department, Meter Division, Westinghouse Elec. & Mfg. Co., Newark, N.J.

Edited by
M. F. BEHAR, Editor of *Instruments*

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The electrical instrument industry has expanded more than 30 times its normal production, but its service facilities in general have not kept up with this pace. Some electrical instrument manufacturers do practically no servicing and cannot promise early return of the few instruments they accept for repairs.

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for Boiler Room Service . . .

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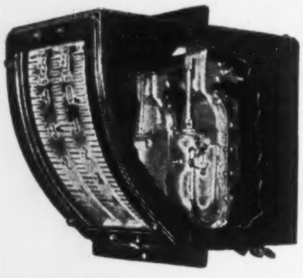
Boiler Meters Reduce fuel costs, lessen maintenance and outage, lower standby costs, and add capacity. They indicate, record and integrate Steam Flow from the boiler, record Air Flow supplied for combustion and record Flue Gas Temperature.

Multi-Pointer Gages for indicating drafts, pressures, differentials are available with any number of pointers from one to twelve. They are actuated by sturdy yet sensitive diaphragm units.



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Flow Meters. For indicating, recording and integrating the flow of steam, feed water, compressed air and other fluids.

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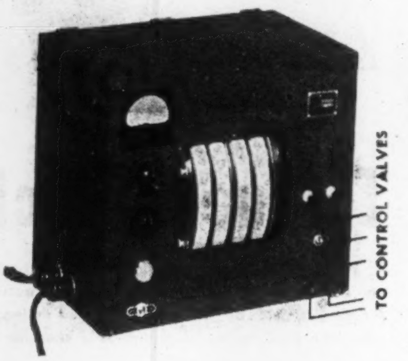
The Month's NEW INSTRUMENTS

In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions. When writing to manufacturers directly, please mention this department. Or write to Information Section, Instruments Publishing Company.

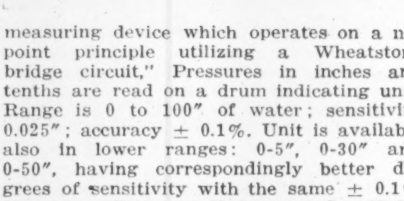
Electric Manometer

New electric manometer changes into electrical readings minute pressures (inches and tenths of inches of water). This is said to be done by "a very sensitive pressure measuring device which operates on a no-point principle utilizing a Wheatstone bridge circuit," Pressures in inches and tenths are read on a drum indicating unit. Range is 0 to 100" of water; sensitivity 0.025"; accuracy ± 0.1%. Unit is available also in lower ranges: 0-5", 0-30" and 0-50", having correspondingly better degrees of sensitivity with the same ± 0.1% accuracy.—*Trimount Instrument Co., 37 W. Van Buren St., Chicago 5, Ill.*



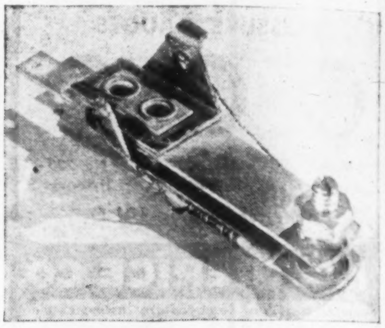
Totally-enclosed Pilot Light

New "Series 1100" Pilot Light is available in several variations. Primarily for ungrounded panels, all variations of new unit are equipped with two solder terminals. Models No. 1110 (faceted jewel) and No. 1111 (plain jewel) take long bulbs; Models No. 1112 (faceted jewel) and No. 1113 (plain jewel) take round bulbs. (Preceding models are available with bayonet sockets only.) New light is also available as a shutter type light, for applications that require variable intensities to satisfy varying conditions. 90° turn of shutter provides gradation from bright light, through intermediate glows to a dim glow, or total blackout. In shutter type—Models No. 1114 (faceted jewel) and No. 1115 (plain jewel) provide for round bulbs. They can also be furnished with polarized lens. All models mount in an 11/16" hole and have ½" jewels. Lamps are removed from front of panel.—*Gothard Manufacturing Co., Springfield, Illinois.*



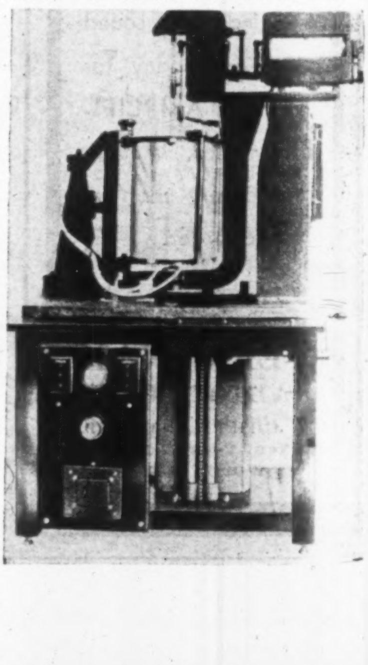
Ambient-compensated Time-delay Switch

New ambient-compensated time-delay switch is ruggedly constructed with contact capacity of 1500 watts, 115/230 volts a.c. Heater windings are wound for 6 to 230 volts. Heavy-duty electrolytic silver contacts, available normally open or closed. Weight ¾ ounce; overall dimensions 2¾" × ¾" × ⅝"; mounted with two 6/32" screws through eyelets having 3/16" centers. Can also be built to individual specifications.—*George Ulanet Co., 88 East Kinney St., Newark 5, N. J.*



Dilatometer

New "Model A-134 Bristol-Rockwell Dilatometer" records temperature-dilation changes and temperature-time changes simultaneously in ink during heating and cooling cycles of ferrous and non-ferrous metals, ceramics, many other materials in solid form. Two records are made on a chart with rectangular coordinates for ease of interpretation and filing. Ball-bearing multiplying mechanism exerts "very light pressure" on sample and is said to provide



The LINK C-N-T synchronizes the operation of its maze of precision instruments with built-in CONSTANT VOLTAGE

The Link Crew Navigation Trainer will go down in history as one of the outstanding scientific contributions to early and complete victory in this war.

Firmly anchored to the ground where a mistake will not be costly in life and equipment, "freshmen" of the united nations' air forces learn the fundamentals of aerial warfare. Thus thousands of lives have been saved, hundreds of bombers released for duty at the front, and thousands of airmen go forth better equipped to master the problems of actual combat.

The Link **C-N-T** is a teamwork trainer for pilot, navigator, radio operator and bombardier. The heavens are accurately reproduced for celestial navigation. The pilot guides his ship over accurately duplicated terrain. The radio operator maintains communication with an airbase. The bombardier "lays his eggs" on the target. And all of these "long range" missions take place in a small, circular building only slightly larger than the familiar silo on our dairy farms.

The results of this careful, safe training have been "more bombs on the targets—more planes and crews safely home."

In order to maintain accurate coordination in all of these various functions a specific operating voltage had to be maintained. Due to the heavy power loads, available voltages were fluctuating over such a wide range that accurate operation of the C-N-T was difficult.

The answer was built-in Sola Constant Voltage Transformers which, regardless of power line fluctuation, duplicated the operating voltage called for on the label.

Here is another typical example of improved product design made possible by automatic, self-protecting Sola Constant Voltage Transformers. Available in standard units from 10VA to 15KVA or custom built to design specifications.

SOLA

Constant Voltage Transformers

To Manufacturers:

Built-in voltage control guarantees the voltage called for on your label. Consult our engineers on details of design specifications.

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Transformers for: Constant Voltage • Cold Cathode Lighting • Mercury Lamps • Series Lighting • Fluorescent Lighting • X-Ray Equipment • Luminous Tube Signs Oil Burner Ignition • Radio • Power • Controls • Signal Systems • Door Bells and Chimes • etc. **SOLA ELECTRIC CO., 2525 Clybourn Ave., Chicago 14, Ill.**

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While we are kept busy now producing thermometers, for which there is yet a critical need, we are not unmindful of your Post War needs.

Palmer Thermometers that have withstood the stress of war duty will be much improved, retaining their fundamental tough quality and their extreme accuracy and sensitiveness for which they have been famous.

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To the Engineer, Physicist or Chemist Who Seeks A PERMANENT JOB

IF YOU are an engineer, physicist, or chemist now working for a company whose war contracts are terminating there may be a permanent job for you with one of the leading instrument manufacturers. Most of these companies are still working full time on war work. As soon as their war contracts are completed, postwar projects will be ready for action with plenty of opportunity for creative development work. Interested? Write Employment Service Instruments Publishing Company, 1117 Wolfendale St., Pittsburgh 12, Pa., giving complete professional and personal data. U.S.E.S. consent and release statement will be required.

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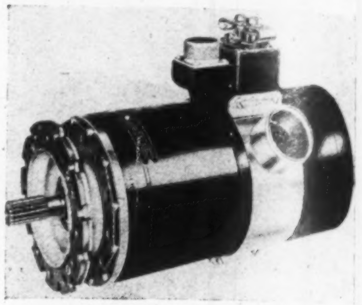
smooth accurate temperature-dilation records. Split furnace, designed for temperatures to 2500°F., can be pulled away from sample for quenching or cooling without disturbing record; inside dimensions allow use of any size or shape of sample up to 1⅝" diam. by 5" long. New dilatometer can be used to determine critical points of carbon steel, coefficients of expansion of metals, thermal composition of metals, Heating rates and heat saturation.—*The Bristol Company, Waterbury 91, Conn.*

Aircraft Power Supply Systems

New "Eclipse AC-DC Power Supply Systems" consist of engine-driven a-c.-d-c. generators and carbon-pile voltage regulators, provide a.c. for operation of communication devices and d.c. for operation of d-c. instruments and other equipment. Generators are designed to mount on main engine generator drive pads of aircraft incorporating provisions for generator blast cooling. They are available in various capacities from 60 to 200 amperes at 28.5 volts d.c. and 10.4 to 30.5 amperes at 115 volts a.c., both outputs being available simultaneously over entire rated speed range. Weight-saving advantages are claimed over systems utilizing separate d-c. and a-c. power supply equipment. Carbon-pile voltage regulators provide continuous regulation without fluctuation, and with a minimum of radio interference by reason of absence of vibrating contacts.—*Eclipse-Pioneer Division, Bendix Aviation Corp., Teterboro, N. J.*



Five-inch Oscilloscope

New "Type 247 Oscillograph," designed to facilitate the investigation of transient as well as recurrent phenomena over a wide frequency range, utilizes new "Army-Navy preferred Type 5CP1" cathode-ray tube with intensifier electrode, operated at an overall accelerating potential of 3000 v. High-intensity patterns are obtained on 5" diameter screen. Medium-persistence green screen is standard. If a permanent record of transient phenomena is required, instrument may be supplied with short-persistence blue

creen for high-speed photographic recordng, or with long-persistence green screen or visual observation of low-speed phenomena. Sweep frequency range has been xtended down to 0.5 c.p.s., providing a ider range of sweep operation. Thus it ay be used for observations on low-speed achinery and for other low-frequency unctions. Time-base provides recurrent, ingle or repetitive sweep operation. An unsual beam control circuit is used with sinle sweep operation, to darken screen exept during actual sweep cycle, providing reduction of background illumination and esulting in photographs of greater conrast. Other features: Exceptionally uniorm response over wide frequency range or both vertical and horizontal axes; a istortionless continuously-variable lowmpedance attenuator or gain control; a Z mplifier channel for applying external timng signal to grid of modulating electrode. Dimensions: 14" w., 19" h., 26" d. Weight 30 lbs.—*Allen B. DuMont Laboratories, nc., Passaic, N. J.*

Sensitive Relay Set

New "SS-5 Relay Set," having been developed primarily for use with maker's "Red-Top Thermo-regulator," if of high-sensitivity haracteristics for use in conjunction with

galvanometers, contact-equipped instruments, gages or other relay-operated instruments that require low-gram contact pressure. It comprises a sensitive iron-core-magnet type relay (which can be operated on 100 volts and 2 milliamps) and a solenoid type mercury plunger relay ,the tube of which will handle a load up to 30 amps at 110 volts a.c., or 20 amps at 220 volts. These two relays are mounted side by side in a 5¾" × 5¼" × 3½" hinge-covered housing, with marked terminal block below the two relays; and a 4-foot armored cable with plug for connection to instrument.—*H-B Instrument Co., 250½ No. Broad St., Philadelphia 32, Pa.*

Gage Blocks

New "Economy Set" of 37 gage blocks has newly designed pocket carrying case which holds blocks on end for ease in handling and identifying. This position also

A Testing Problem

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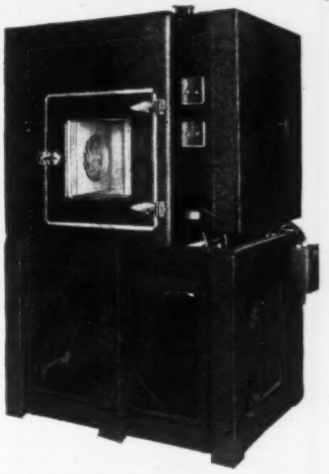
FOR A MANUFACTURER OF PRECISION PARTS



CONDITIONS

1 From room temperature to +120°F. and 95% relative humidity to a stabilized condition in 35 minutes and hold for 2 hours.

2 Repeat cycle four times.

3 Go to −95°F. in 100 minutes and hold for 1 hour.

4 Increase temperature to +160°F. in 60 minutes and hold for 2 hours.

5 Return to room temperature.

ACCOMPLISHMENT

This test was completed with Model RTC-3AA equipped with Humidity Control, and without opening the door. All cycles were automatically controlled by previous manual setting.

AMCOIL MAKES TESTS TO YOUR ORDER

To accommodate manufacturers of radio parts, precision instruments and similar products, American Coils Co. has developed this improved RTC-3AA Testing Chamber with Humidity Control. Compact in design, it occupies less floor space than other models and may be installed in multiple batteries for testing component parts.

This RTC-3AA Model is a self-contained unit with a testing area of 9 cu. ft. The cabinet has an insulated hole 3" in diameter arranged so that various plugs for supplying electrical energy or mechanical movement to parts during the testing operation may be installed. Other Amcoil types are equipped for dry ice or mechanical refrigeration for accurately simulating service conditions with respect to altitude, humidity, heat and cold. Testing areas range from 7 to 32.5 cu. ft., and temperatures from −95° F. to +158.8° F.

AT YOUR SERVICE

AMCOIL engineers offer an authoritative consulting service to manufacturers interested in testing parts or instruments under various temperatures, pressures and humidity conditions.

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LUXTRON
PHOTOCELLS

Luxtron* Photo-Electric Cells Operate Instruments and Instrument Relays Without Auxiliary Voltage or Amplification.

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PHOTOELECTRIC CELL

This pigtail-contact model is only one of a series of mountings and indicates only one of the complete range of Luxtron* cell shapes and sizes available.

Their high-efficiency conversion of light energy into electric power, permits applications in great variety.

Bulk and complexities are minimized. War applications impress their dependability and durability daily.

Luxtron* Photocells are wholly American in both materials and manufacture.

Send for illustrated, engineering literature and let us co-operate with you on special problems and applications.
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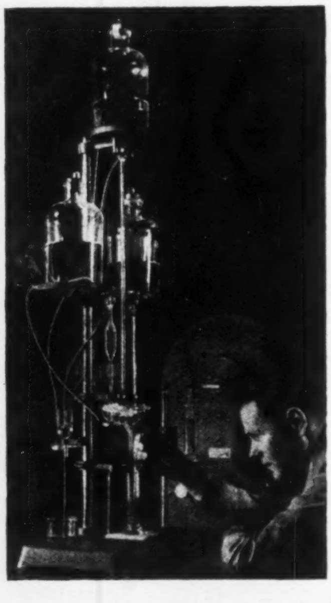
82 Meadow Street, New Haven 10, Conn.

prevents grit and dust from settling on polished measuring surface. Case measures 7½″ × 4″ × 2″ to fit in inspector's shopcoat pocket. Set includes two 0.050″ wear blocks in addition to five standard series: First series, 9 blocks: 0.1001″ to and including 0.1009″ in increments of 0.0001″; second series, 9 blocks: 0.101″ to and incl. 0.109″ in increments of 0.001″; third, 9 blocks: 0.110″ to 0.190″ in 0.010″; fourth, 5 blocks: 0.100″ to 0.500″ in 0.100″; fifth, 3 blocks: 1.0″, 2.0″, and 4.0″. These blocks when wrung altogether give an overall measurement of 11.7995″. Any measurement from 0.050″ to 11.7995″, in increments of 0.0001″ can be made with millionth accuracy, using various size blocks in combination. Gage blocks are available in two qualities: Set "A"—"Inspection Quality" is guaranteed in height, flatness, and parallelism accuracy within ±0.000004″ at 68°F. Set "B"—"Working Quality" is guaranteed in height, flatness, and parallelism accuracy to within ±0.000008″ at 68°F. Blocks are said to be made from special analysis steel to give long wearing quality. Each is heat-treated, seasoned and processed to insure absence of internal stresses, warping, growth, or shrinkage. Each has a hardness of 65 Rockwell "C" and is etched showing dimensional size and serial number.—*Continental Machines, Inc., 1301 Washington Avenue So., Minneapolis 4, Minn.*

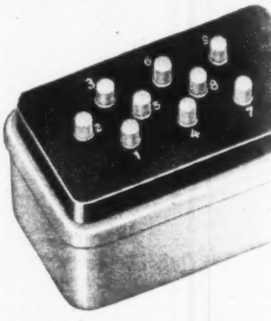
Sulphur Determination Apparatus

New "Three Minute Sulfur Determinator" is for rapid and accurate sulphur determination of all steel, iron, non-ferrous metals, and materials such as coal and coke. Sample is ignited in a high-temperature furnace in an oxygen atmosphere. Sulphur in sample is converted to sulphur dioxide gas. It is filtered free of all dust particles by a hot ceramic filter within furnace combustion tube. SO_2 gas then bubbles through an alkaline solution which reduces alkalinity of this solution. Alkalinity is measured by titrating with a standard acid solution. New apparatus is divided into two units: measuring burettes with 2 liter solution bottles are mounted on one unit; other unit consists of a stand and support for holding solution vessel at furnace. This arrangement increases speed with which sulphur determination may be made since one sample may be in process of combustion while another sample is being titrated. Sulphur percentage is read direct from burette scale. Gas bubbler is separated from solution vessel, allowing these parts to be of inexpensive construction and easy to clean. So-



COPROX
RECTIFIERS

Coprox Rectifiers Have Conservative Ratings, Excellent Stability, Longer Life. Gold Coating Delays Aging.



Shown above is Coprox BX-22.3 double bridge rectifier with current and temperature-current characteristics balanced to better than 1% over a range of —40°C to +70°C. Rated up to 4.5 volts AC, 3 volts DC, 5 milliamperes DC. Other models and capacities to meet all needs.

In Coprox Rectifiers, gold coating on the positive contact "pellets" delays aging. Presoldered lead wires or special terminals, prevent overheating during assembly.

Standard units are sealed with waterproof lacquers. Critical-application units are potted in wax. Standard mountings are adaptable.

Ratings are conservative and very latest technical advances warrant unusually high testing standards.

Bradley has the experience to meet unusual rectifier problems. Write for data.

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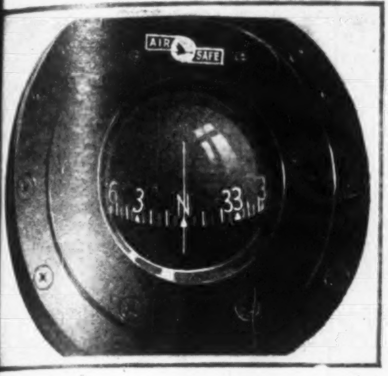
tion bottles hold ample amounts of preared solutions and may be quickly reoved for refilling. A special blue reflector ith a frosted glass base causes end point be a distinct color change from yellow blue.—*Harry W. Dietert Co., 9330 Roseon Ave., Detroit 4, Mich.*

rcraft Compass

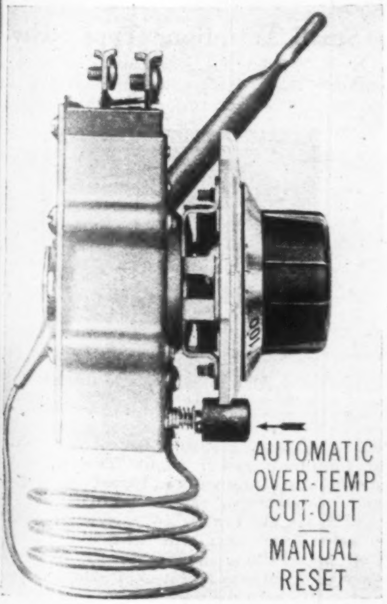
New "Airsafe Compass" is claimed to mbody design and construction features hich eliminate troubles and disadvantages uch as fragile compensating bellows, ex-



essive weight, excessive swinging of cards, ials too small for easy reading, breakable enses, etc. New instrument's case is plastic nd magnet is Alnico, so that weight is 6-oz. Metal bellows are replaced by synhetic rubber. Dial is designed for "quick asy reading from anywhere in the plane," as radium-painted numerals and markngs, is read through an "unbreakable bull's-ye" lens. Furthermore, it is said that new ompass "lends itself to modern production-ine methods of assembling airplanes" and eets Army and Navy specifications.—*irsafe Aircraft Instrument Co., 3722 San ernando Rd., Glendale 4, Calif.*

lectric-contact Type Automatic Temperature Controller

New "H 1 Electric Temperature Control" ith manual reset over-heating cut-off feaure consists of maker's standard "Model 1" d-p. s-t. electric temperature controler equipped with an auxiliary s-p. s-t. witch which will automatically cut off all urrent as soon as operating temperature is xceeded by 30°F. in liquid or 50°F. in air y reason of negligence, fusing of thermotatically-operated contacts, etc. During



Shallcross

KELVIN-WHEATSTONE BRIDGE Type 638-2

0.0001 ohms to 11.11 megohms

WIDE MEASUREMENT RANGE
in a single instrument

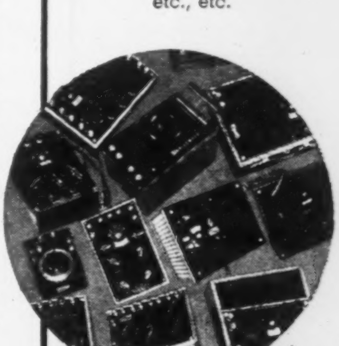
Combining both Kelvin and Wheatstone bridges, this popular Shallcross instrument provides a resistance measurement range from 0.0001 ohm to 11.11 megohms in a single portable unit. Widespread use is proving it unexcelled for laboratory and school work, maintenance, many forms of production line testing, field investigations—in fact, for use almost any place where electrical resistance is measured.

When used as a Wheatstone bridge for measurements between 1 ohm and 1 megohm, the normal accuracy is better than 0.3%. Low resistance measurements using the Kelvin range utilize current and potential terminals to eliminate lead and contact resistance. The accuracy of Kelvin measurements is normally 3% or better.

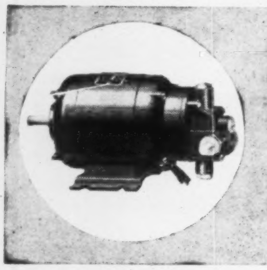
Ask for details on Kelvin-Wheatstone Bridge Type 638-2.

Write for literature on other Shallcross Instruments

Megohmmeters
Percent Limit Bridges
High Voltage Instruments
Kilovoltmeters
Fault Location Bridges
Low-Resistance Test Sets
etc., etc.



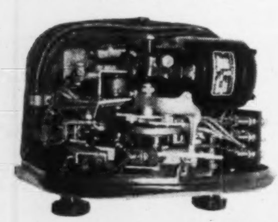
SHALLCROSS MANUFACTURING COMPANY
ENGINEERING • MANUFACTURING • DESIGNING
DEPARTMENT IS-54 COLLINGDALE, PA.



PRECISION MOTORS
for important
instrument applications

The Bodine NSY-12R motor, used on the instrument illustrated below, is a 1/75 hp synchronous type with 288:1 integral worm gear speed reducer. It is single phase, resistance start, giving good momentary overload characteristics. It is a reliable motor—quiet in operation and a space-saver.

TYPICAL APPLICATION—Used in Picker X-Ray Timer developed by Picker X-Ray Corporation.



Instrument making is a precision business. Therefore materials and workmanship must meet the strictest specifications.

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The majority of Bodine customers are repeat buyers who have standardized on Bodine motors year after year. Such loyalty is evidence of a good product—the reward for over 35 years of dependable service. Bodine Electric Company, 2244 W. Ohio Street, Chicago 12, Illinois.

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MOISTURE CONTENT
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THREE SECONDS

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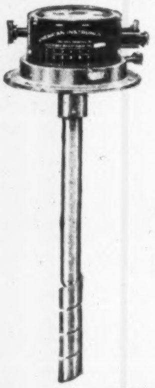

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"QUICKSET" BIMETAL
THERMOREGULATOR

Range: —73° to 538°C.
Sensitivity: ±0.05°C. for liquids; ±0.01°C. for air (or better).
Quickly adjusted to desired temperature.

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Range: —30° to 250°C.
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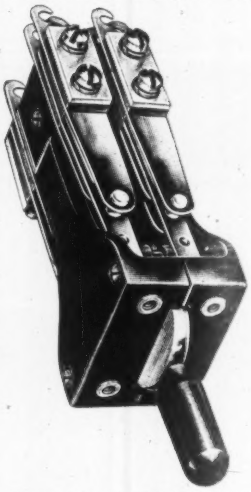
normal operation this controller will brea both sides of line. In case of excessive tem-peratures, safety contact (auxiliary switch) is broken on one line only and this is suf-ficient to break circuit to heating element Circuit is made through contacts of limiting device by pushing in on manually-operated reset button. Contact is then made and held in place by a locking device, or safety catch which is not disturbed by normal operation and does not operate until excess temperatures create an additional expansion of diaphragm raising safety catch and causing contacts to separate. This break of contact will occur even if main contacts have be-come fused. A limit control without the temperature controlling mechanism is also available.—*Commercial and Industrial Div., Robertshaw Thermostat Co., 39 Church St., New York 7, N. Y.*

3-oz. Multi-circuit Switch

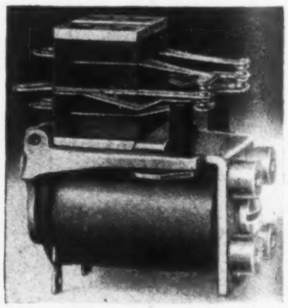
New "Maco Featherweight Switch" has frame molded of high-impact phenolic (Navy Spec. 17P4 CFI-20) by Navy-approved molders, advantages being high



dielectric strength, mechanical rigidity and uniformity of switch elements. Knurled inserts with ¼″ thread depth are provided (on ⅝″ × 1¼″ centers) and are locked in place. Newly-designed hook-type solder terminals are tinned all over. Coin silver contacts in phosphor-bronze spring leaves carry 10 amps a-c. or 2 amps d-c. at 11 volts, may be ganged in any desired number and combination and for locking or spring-return in either lever position.—*Metallic Arts Co., 243 Broadway, Cambridge, Mass.*

Small Telephone Type Relay

New "Model TKL" is latest addition to maker's line of telephone type relays said to be developed for maximum magnetic



efficiency with resultant sensitive operation at minimum power input. This relay was specifically designed for high-frequency use and incorporates Mycalex insulation but can be supplied with approved Bakelite insulation for standard switching service. Coil is cellulose acetate sealed for resistance to humidity. Relay will meet all standard salt spray specifications; will with-

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A Word about Our Production Facilities

We can handle and are handling big orders for permanent magnets . . . handling orders from many exacting manufacturers of electronics equipment including Sperry, Philco, Galvin Motorola, Raytheon, Bendix and others.

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Among the steels going into our magnets are ALNICO and NIPERMAG, two metals of exceptionally high energy product.

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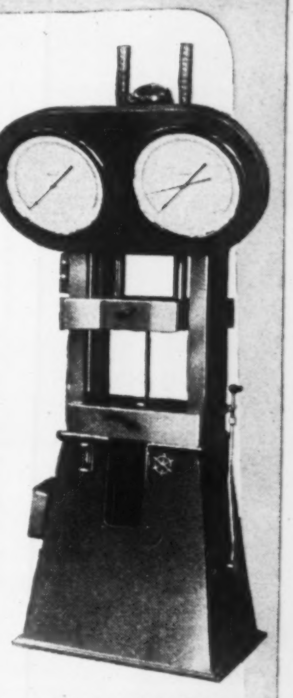
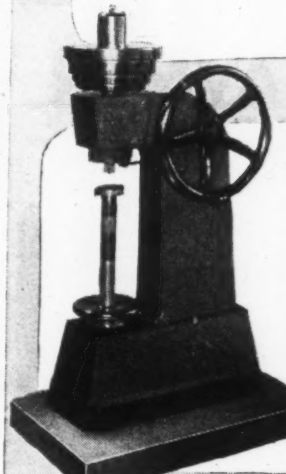
Model 505 RIEHLE is the most accurate, economical and reliable testing machine within its group today. It has two motor drives, one for hydraulic loading, and the second for fast vertical adjustment of gripping head and table. The spherically suspended gripping head and table assure consistent accuracy even with loads applied off-center. Capacities up to and including 60,000 pounds. Coincidence between dial graduations and the accurately applied testing loads from minimum to maximum is established by means of a proving ring, accurately calibrated by the National Bureau of Standards.



Model 505 Hydraulic Testing Machine



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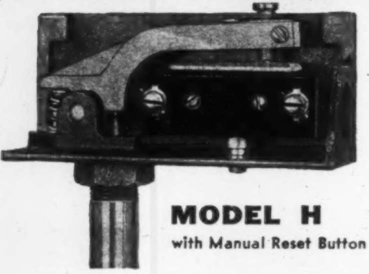

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with Manual Reset Button

Available with switch normally closed for cutting off heat, stopping fan, closing valve —with switch normally open for lighting lamp or ringing bell—with single pole double throw switch . . . breaks heating circuit while closing alarm circuit. Sturdy, fool-proof reset button operates from outside case. Range 0-1400° F; adjustable range 200-300° F. Dimensions: 5⅛" x 1¾" x 3". Dial Pointer for easy setting.

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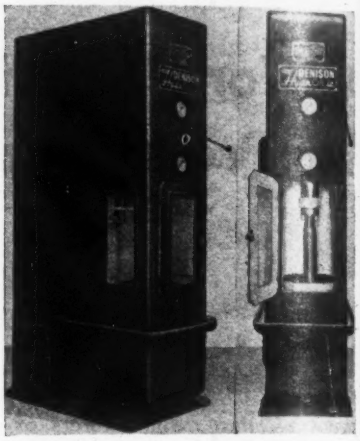
stand shock and vibration to 10 G. Normally, contacts are of palladium for maximum sensitivity but fine silver or special alloy contacts are available on request. Double pile-ups of contacts can be supplied from a single "A" (SPSTNO), "B" (SPSTNC) or "C" (SPDT) arrangement to a maximum of four "C" combinations. Weight and dimensions, less contact pile-ups: 1¼ ounces; $1\frac{7}{16}''$ long × $\frac{15}{16}''$ wide × $1\frac{1}{16}''$ high. Special tapped studs, brazed to frame, permit easy mounting and prevent short-circuiting of coil.—*Allied Control Co., Inc., 2 East End Avenue, New York [illegible], N. Y.*

Hydrostatic Test Press

New hydrostatic test press is said to be of special interest to those engaged in determination of specifications, is claimed to simplify testing of drawing qualities of



metals, fatigue, influence of heat treatment, etc. Coatings such as paints, enamels and plastics can be tested by alternate applications of pressure, simulating expansion and contraction. External pressure may be employed to determine strength of all types of containers. Porosity and seepage values are obtained through uniform application of pressure. New press is said to feature simplicity and convenience of operation; clamping portion makes it possible to test articles of various heights without retooling.—*The Denison Engineering Co., Columbus, Ohio.*

Aircraft Lighting System Transformer

New transformer is intended for use in aircraft applications where a high temperature will not afford satisfactory service. Its

total weight of 8 oz. is said to be approximately 40% less than nearest comparable transformer of equal output. Its low temperature rise of 30°C. will permit operation over all ambient temperatures from -65°C. to 70°C., and altitudes up to 50,000 feet. Design is said to be conservative with regard to both electrical and mechanical characteristics. Reduction in weight is said to have been made possible by using latest engineering techniques and materials. For special applications, output voltages and

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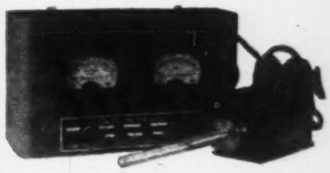

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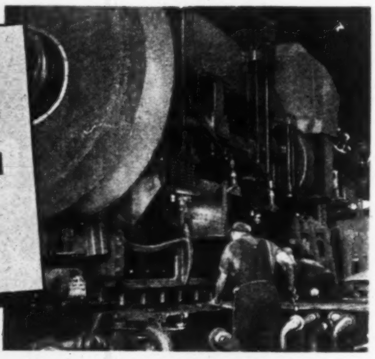

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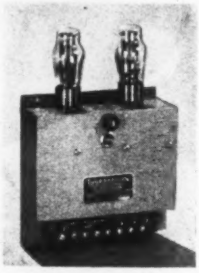

Model T-50 x 40
Power Source—115 Volt 60 c. p. s.
Control Circuit—Operation of one pair of contacts produces orientation of power output.
Output—Two circuits supply 115 Volts up to 40 V. A.—Only one output circuit functions at any given instant. Other sizes available, special order.

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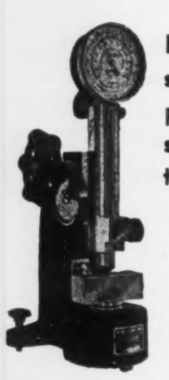

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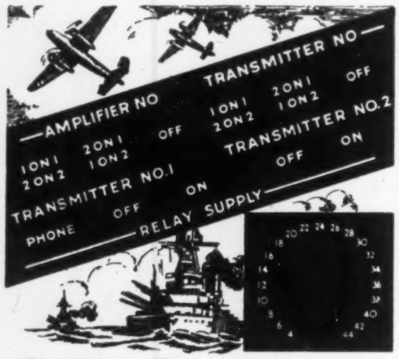

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currents may be varied without affectin size and weight, if output is held to 30 va.—*New York Transformer Co., [illegible] West Thir St., New York City.*

Ultraviolet-transmitting Filters Opaque to Visible Light for Converting F-1 Lamps

Development of a plastic filter transmitting invisible untra-violet radiatio from a white-light fluorescent lamp an filtering out visible light, has been achieve by J. M. Gordon, Fluorescent Plastic Co sultant and research engineer for unde signed manufacturers. New plastic filte can be used with any size fluorescent tubular style lamp or circular type contemplated for production. It is also availab for the two-watt and four-watt RP1 fluorescent airplane lamps and 4-watt T six-inch lamp. It is said that this filter an lamp combination, producing require black-light effect, costs a fraction of present u-v. sources such as mercury-vapor o carbon-arc lamps requiring transformer and accessories and generating intens heat. In connection with fluorescent-treate instrument and radio dials, a variety o color combinations and effects can be produced: by utilizing additional feature available in new plastic filter, rotatin around the lamp, u-v. rays can be synchronized with the scales on the dial switche on, and the other scales blacked-out.—*Lio Manufacturing Corp., 135 S. LaSalle St Chicago (3), Ill.*

Snap-action Relay Re-designed fo General Use

"Type 79XAX Sensitive Snap-action Relay" was first introduced in higher-price field as an overload unit for protecting an electron microscope, design simplification now makes it both practical and economical for use in a wide variety of applications. It is said that in addition to all better-known advantages of conventional sensitive relays, "Type 79XAX" is designed so that its armature practically completes its travel before contacts snap with a positive action to corresponding position. This (plus fact that contacts remain closed with full pressure up to instant of transfer to other position) is said to permit unit to be used in a number of unusual ways: overcurrent protection, particularly in range of 1 to 100 milliamperes; overcurrent protection in connection with shunts furnishing potentials in range of 1 to 100 millivolts; pulsing circuits where relay must "pump" or "scratch its own back"; numerous sensitive vacuum-tube circuits; etc. Normal sensitivity is 0.01 watt, although a greater degree of sensitivity may be obtained by means of various circuit arrangements. Contact arrangement is S.P.D.T. and contact rating 10 amps. 110-volt a.c. and 10 amps. 24-v.d.c. Balanced construction withstands 10*G* vibration and shock. Coil resistance available from ¼ to approx. 30,000 ohms. Weight 10 ounces; size 2¾" × 3" × 1¾". — *Struthers-Dunn, Inc., 1321 Arch Street, Philadelphia 7, Pa.*

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New "Limitrol" is said to be "a revolutionary comparator type roll snap gage" which can be used either as a hand or bench type gage and which "performs six inspection operations in one: it checks pitch diameter, lead, taper, angle, straightness and out of roundness." It is available with plain and threaded rolls, in both open-end and closed-end models, in six nominal sizes: ¼", ⅜", ½", ⅝", ¾", ⅞", each being adjustable ⅛" either way from nominal size. Thread diameters from No. [illegible] to 1" can be gaged. Rolls are provided in ⅜", ⅝" and 1" widths. For gaging parts with a .004" tolerance or less, magnification of 250 × is provided; 150 × for parts with greater tolerance. Maker claims that "Limitrol has been known to speed up in-

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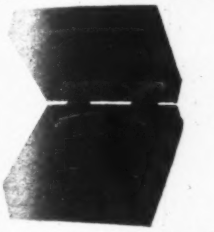

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Bulletin 504
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Portable Standard with single electrical zero return.

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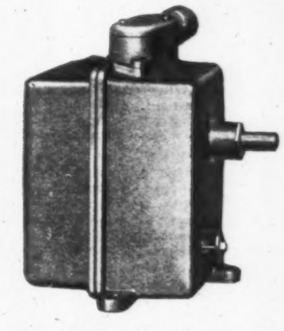

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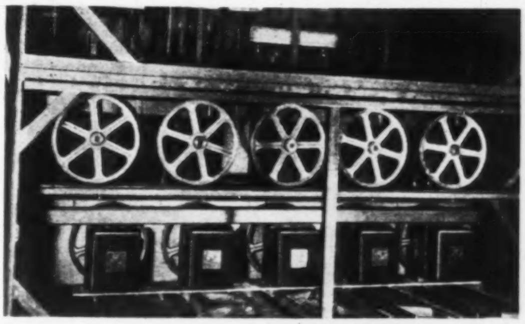
Are you designing an instrument that needs an electric motor-operated unit for cycling, for operating, for adjusting, for switching, or for some similar purpose? Then consider the use of a Barber-Colman Power Unit. They are available in various types and sizes and are effective in numerous applications. Tell us your requirements and let us see if we can meet them.



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A recent application of B-C controls — on Trimount's portable Multiple Manometer for wind tunnel laboratories. Ten switch-controlled AYCK Power Units raise or lower the variable wells to set levels at any desired point.

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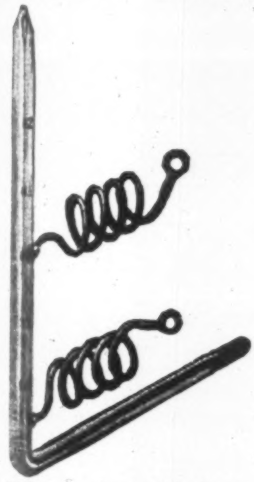

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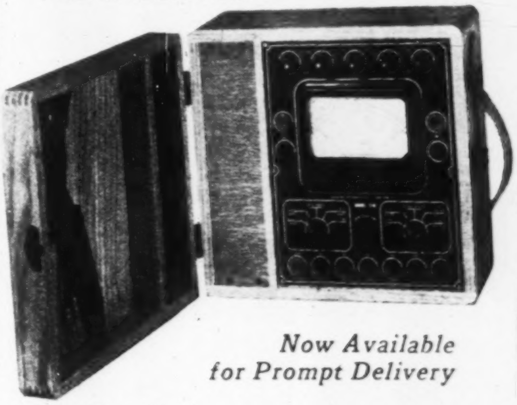

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Sensitivity —
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ON BOTH A.C. AND D.C.!!

Measures:—
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Model 710 uses a 4½" square 0 to 400 Microampere meter. All calibrations printed directly on meter scale in large easy-to-read type. Instrument is housed in rugged, heavy-duty Oak cabinet. Operates on self-contained batteries—no external source of current required. Comes complete with self-contained batteries, test leads and instructions. Size 6" x 10" x 10".

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To the combat pilot, high up in the inky blackness of night, the glowing instruments are more than mechanism . . . they're his security, his strategy and his return ticket! These lights must not fail!

To further this dependability in aircraft lighting systems, the N.Y.T. Sample Department has produced the 8 ounce transformer illustrated below—lighter in weight by 40% than any component of the same output previously used. Conservative, from the standpoint of electrical and mechanical characteristics, this N.Y.T. unit has a temperature rise of only 30 deg. C. and permits operation over all ambient from minus 65 deg. C. to plus 70 deg. C. Its diversity of application is illustrated by the fact that output voltages and currents may be varied without affecting size and weight, if the output is held to 30 V.A.

This is but one of the many custom-engineerings executed by N-Y-T technicians, in hastening Victory through electronics; similar transformer products will aid immeasurably in the fulfillment of peacetime advancements.

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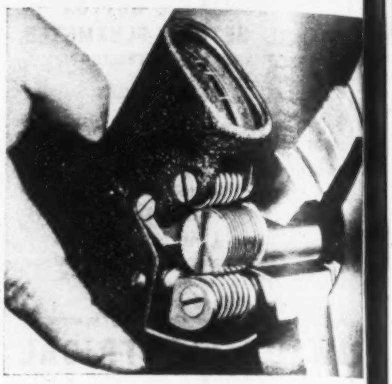
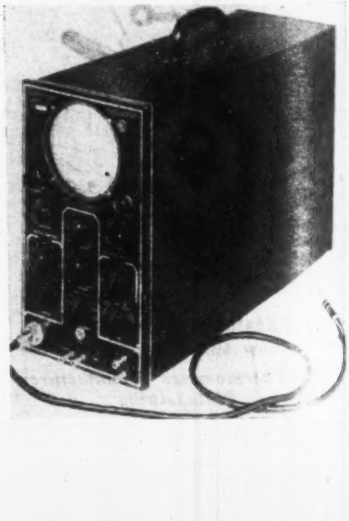


spection operations as much as four time the original speed." Different pitch roller are interchangeable; may be replaced less than five minutes. To set, place master between rolls and turn adjustin screw on bottom of gage until indicato arm moves up under proper limit bar.— *N. A. Woodworth Co., Ferndale, Detroi Mich.*

Five-inch Oscilloscope

New "Model 550-A" cathode-ray oscillo scope is said to be of universal applicatio its design permitting study of comple wave-forms such as square waves an pulses encountered in television work Square wave signals from 40 c.p.s. to kc. can be accurately reproduced, it is said Vertical amplifier has a sine wave fre quency response of 500 kc. ± 1 db. Re sponse at 1 Mc. is high enough to mak "Model 550-A" useful at this frequency Gain of vertical amplifier is high enoug so it may be used for low-level a.f. mea surement. Voltage gain is 625. Oscillosco is equipped with a detachable co-axia cable with input capacitance of 8 mmfd which low capacitance minimizes detunin or excessive loading of circuit under tes Compensated 4-step attenuator permit



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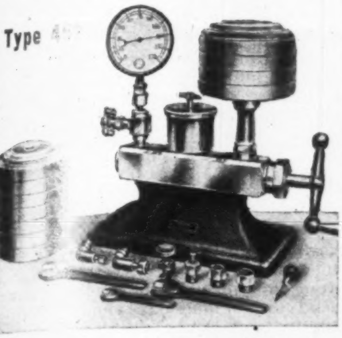

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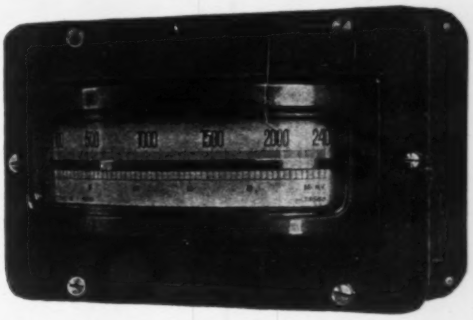

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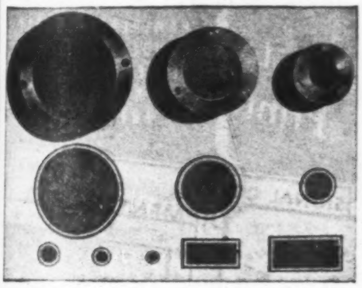

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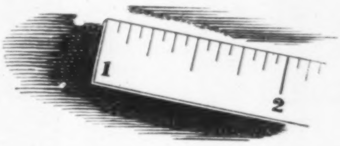

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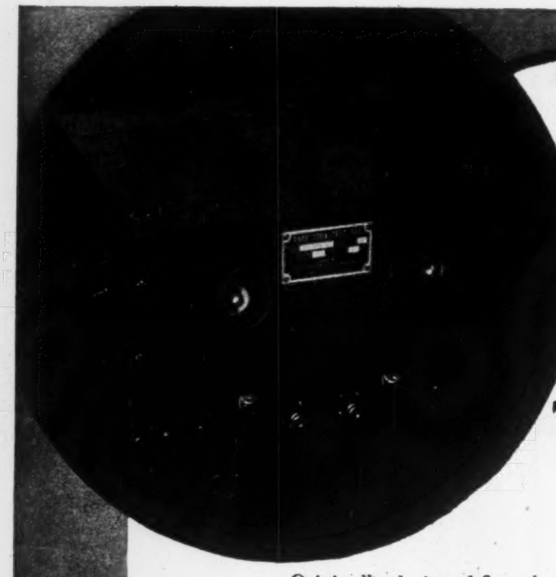

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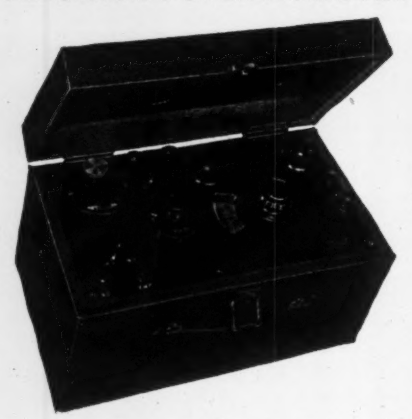

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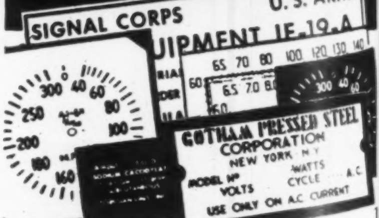

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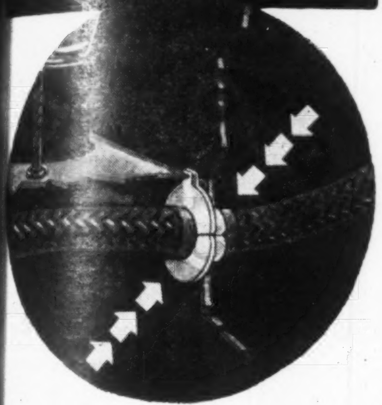

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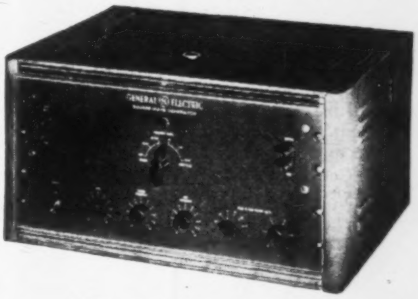

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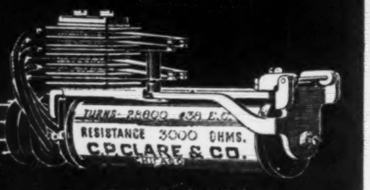

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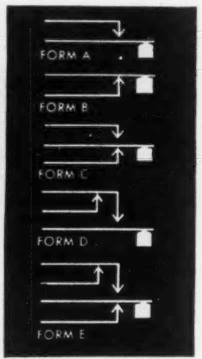

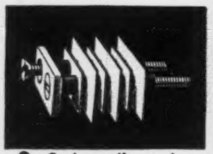

2. Spring pile-up insulators of heat treated Bakelite which permit punching without cracks, have minimum cold flow and low moisture absorption content. Assembly locked together under hydraulic pressure. Withstands heavy breakdown tests.

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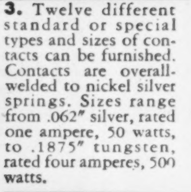
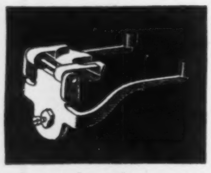


5. Armature assembly single or double arm. Has stainless steel shaft, operating in a marine brass yoke. Heel piece, coil core and armature are magnetic metal carefully annealed. Designed for d.c. service.



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L-78 **Cenco News Chats.** 7¾" × 10¾". 20 pages. The December issue contains information of scientific interest, and features an article paying tribute to Dayton C. Miller, "* * * a great American who dedicated his life to the service of science." Central Scientific Company, 1700 Irving Park Rd., Chicago 13, Ill.

L-79 **Ohmite News.** 8½" × 11". 2 pages. December, 1943 Issue contains an article on high frequency induction heating frequency equipment. Ohmite Mfg. Co., 4826 W. Flournoy St., Chicago, Ill.

L-80 **C-D Capacitor.** December issue, 5¼" × 7½". 16 pages. Contains two articles of general interest to electronics men. One describes three types of circuit networks to compensate overall response of crystal phono pickups to improve performance. The second article, technical in nature, presents a simplified solution of general problems concerning amplifier response characteristics. Cornell-Dubilier Electric Corp., 1049 Hamilton Blvd., So. Plainfield, N. J.

L-81 **Mercurial Thermostats.** Bulletin 344, 3¾" × 8½". 6 pages. Response to changes in temperature is based upon expansion or contraction of mercury within a glass tube. Electrical contact, for controlling purposes, is made when mercury touches two contacts hermetically sealed in a glass tube. The straight and angle types illustrated in this publication have a temperature range from 32° F. to 160° F., and a tolerance or accuracy as close as plus or minus .02° F. Features and dimensions included. Bender Scientific Glass, Inc., 2529 North Carlisle St., Philadelphia, Pa.

L-82 **General Radio Experimenter.** December issue, 6" × 9¼", 8 pages. Continuation of a technical writing on "Measurements of the Characteristics of Transmission Lines." Part II in this issue. "Impedance Measurement on Terminated Line," considers five methods of measuring the characteristic impedance of a line, and the relative merits of each method. General Radio Company, 30 State St., Cambridge 39, Mass.

L-83 **Air Craft Suction and Air Pressure Systems.** Check Chart 3, 8½" × 11". 4 pages. Contains a quick-reference specification chart of suction-air pressure systems and components for aircraft. Chart shows the correct engine driven air pump, oil separator, etc., required on certain systems having AAF designations such as B-8A, B-11A, and H-1. Sectional view of engine driven air pump, photographs, and a schematic diagram of a B-8A system supplement check chart. Eclipse-Pioneer, Div. Bendix Aviation Corp., Teterboro, N. J.

L-84 **R. P. M. Controls for A-c. Lines.** Dimension Sheet 173, 8½" × 11", 4 pages. Dimensions and typical performance curves of electronic control equipment for speed regulation of d.c. motors. Power for d.c. motors is derived from A.C. lines by means of electronic equipment covered in this publication. Electronic Equipment Corp., Palm Springs, Calif.

L-85 **"The Graphic."** Bulletin 242, 8 × 11", 4 pages. Reviews interesting a unusual applications of graphic elect cal instruments in various industr fields. Numerous illustrations are i cluded among which are several repr ductions of actual charts made on pa ticularly interesting tests. Esterlin Angus Company, Inc., Indianapolis, In

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